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Final

Midway Landfill Feasibility Study
Treatability Study Report

Seattle Engineering Department
Solid Waste Utility

October 1990

Parametrix, Inc.

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Mr. Harris Martin
Seattle Engineering Dept.
Solid Waste Utility
710 2nd Avenue, Suite 750
Seattle, WA 98104

October 10, 1990
55-1550-22 (138)

re: Midway Landfill Treatability Study Final Report

Dear Mr. Martin:

We are pleased to submit 25 copies of the final of the Midway Landfill Feasibility Study Treatability Study Report.

This report focuses on the identification of technologies and the development of alternatives for treatment of the landfill leachate. It does not address the leachate extraction system or the system to convey the treated effluent to the Des Moines Sewer District. The data from this report is combined with those components and their costs in the associated groundwater feasibility study.

As always, please feel free to contact us with any questions.

Sincerely,

PARAMETRIX, INC.

William F. Kane

William F. Kane
Project Manager

Clyde Moore, P.E.
Senior Project Manager

Enclosures

MIDWAY LANDFILL FEASIBILITY STUDY
TREATABILITY STUDY REPORT

Prepared for

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Solid Waste Division
710 2nd Avenue, Suite 750
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ENVIROS CORPORATION

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1. INTRODUCTION

In 1986, the U.S. Environmental Protection Agency (EPA) placed the Midway Landfill on the National Priorities List (NPL) of hazardous waste sites. Midway is a municipal landfill located in south King County. The landfill was placed on the list because of offsite groundwater contamination and the location of drinking water supply wells within three miles of the site. Groundwater contamination, in part from leachate generated at the landfill, was detected adjacent to the site.

Leachate is generated when water or other liquids enter the landfill, flow through its refuse, and leach soluble chemicals from the refuse. The vast majority of leachate from the Midway Landfill is an aqueous phase liquid (APL) and is formed when water enters the landfill through (1) groundwater inflow, (2) direct infiltration of surface water through the soil cap, and (3) piped flow of surface water from the Linda Heights area (Figure 1.1). A small amount of floating, nonaqueous phase liquid (NAPL) has been detected at the landfill. The NAPL appears to be oil contaminated with polychlorinated biphenyls (PCBs). No solvent phases of the leachate have been detected.

The Midway Landfill was originally a surface water drainage basin for the surrounding area. Various emergency response actions at the landfill, such as surface grading, have modified the existing drainage patterns. However, contaminated APL is still being generated from surface and groundwater entering the landfill and contacting the refuse. The APL drains through the base of the refuse into a deep groundwater system. Presently, the site has insufficient natural or man-made barriers to prevent the APL from contaminating the underlying groundwater system and keep the groundwater from travelling beyond the boundaries of the landfill. However, there are currently no pathways that would expose humans to the contamination. In addition, there are no pathways for exposure to the NAPL. Based on sampling of all wells at the Midway Landfill, the NAPL has been found only in interior gas extraction wells and one leachate well. This detection supports the conclusion that the NAPL is confined to only the central portion of the landfill (AGI 1990).

Remedial alternatives considered for cleanup of the Midway Landfill include extracting and treating the leachate. However, because the physical and chemical properties of leachate vary widely between different landfills, it is not possible to determine theoretically which treatment technologies would be most appropriate for the leachate at Midway. This treatability study was performed to screen possible technologies and test them in the laboratory to determine which would be best suited to treat the Midway leachate. Results from this treatability study will be integrated into the remedial alternatives developed in the associated feasibility study report.

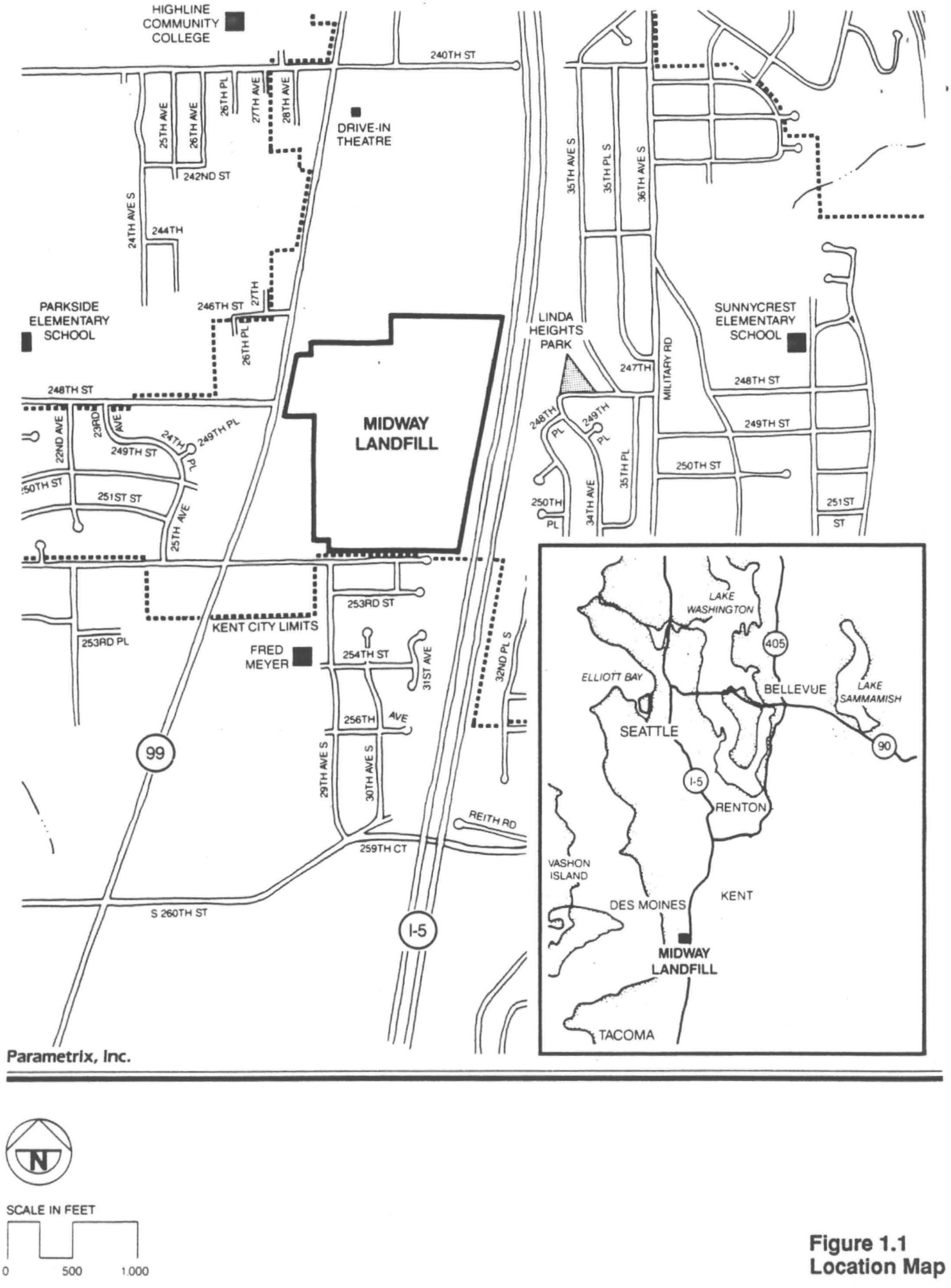


Figure 1.1
Location Map

1.1 OVERVIEW OF THE TREATABILITY STUDY

In accordance with EPA guidance (EPA 1988), a work plan was developed for conducting the treatability study (Appendix A). The plan identified preliminary treatment goals for the leachate, and technologies that had the potential to attain these goals. Because it was unknown if the identified technologies could provide sufficient treatment alone or whether follow-up treatment would also be needed, the treatability study was divided into the following phases:

- Qualitative
- Phase I
- Phase II
- Phase III.

The purpose of the qualitative phase was to observe the general properties of the leachate, including the formation and settling of a precipitate, the partitioning of distinct phases, and the generation and characteristics of foam, under various processing conditions. These observations would allow better configuration of the Phase I experiments. Phase I evaluated technologies that were believed to be solely capable of reducing the contaminant concentrations in the leachate to levels that would satisfy the cleanup standards. No additional treatment of the leachate would be necessary. Phase II, if necessary, was planned to further treat the Midway leachate if it was demonstrated the Phase I technologies did not provide complete treatment in order to satisfy the cleanup standards. The Phase II technologies were polishing steps to further reduce the concentration of contaminants in the leachate. Phase III combined the most appropriate treatment technologies from the phase experiments into a process train. Leachate was then processed through the system in triplicate to determine the variability of the effluent quality and the degree to which the treatment goals could be surpassed.

1.2 ASSOCIATED STUDIES

The City of Seattle, owner of the site, contracted Parametrix and its subcontractors, Applied Geotechnology, Inc., Enviros Corporation, and ICF, Inc., to conduct a remedial investigation (RI), endangerment assessment (EA), and feasibility study (FS) of the Midway Landfill. These studies are part of the remediation procedure mandated by the *Comprehensive Environmental Response, Compensation and Liability Act* of 1980 (CERCLA), as amended in 1986 under the *Superfund Amendments and Reauthorization Act* (SARA).

The Midway Landfill RI, completed in 1988, characterized the nature and extent of the contamination at the site. The RI is described in detail in a set of five RI technical reports (Parametrix 1988). The Midway FS and associated EA are divided into two parts. Part 1 of the FS and EA focus on the pathways of contaminant exposure and the associated health risks through air, gas, and storm water (Parametrix 1990).

Since the FS Part 1 was completed, surface drainage improvements have been made to route surface water to an onsite detention pond. A final gas control system has also been implemented at the site. This system has effectively prevented the migration of gas from the surface of the landfill into the air, and beyond the boundaries of the site through the soil. This system also destroys the collected gases through permitted controlled combustion in the landfill flares.

Part 2 of the EA discusses the present and future risks posed by the Midway groundwater and leachate contaminants to receptors through exposure pathways (Parametrix 1990a).

Part 2 of the FS focuses on pathways of contaminant exposure through groundwater, surface water, seeps, and soil. The purpose of the study is to identify and evaluate alternative remedial actions for cleanup of the site, as well as determine the extent to which those actions mitigate or minimize present and future human exposure to the contamination. The FS Part 2 identifies remedial technologies and alternatives for treatment of the contaminated groundwater at Midway. The treatability study report presented here is a subpart of the FS Part 2, and identifies and evaluates options for treatment of the Midway leachate.

1.3 OBJECTIVE OF THE TREATABILITY STUDY

The objective of the treatability study was to identify, evaluate, and screen remedial technologies and combine them into alternatives that would be potentially applicable for treatment of the contaminated APL from the Midway Landfill. The most promising remedial processes were then bench-tested in the laboratory to determine those that would be technically and economically feasible for use at the site. This report provides the necessary information on each treatment alternative to allow the City and the Washington State Department of Ecology (Ecology) to select the most acceptable treatment process for the APL. The options available for extraction of the leachate from the landfill and reduction of the leachate volume will be identified and evaluated in the associated feasibility study report.

To evaluate which processes would be technically feasible for treatment of the Midway APL, the treatability study experiments were conducted under conditions that are likely to be encountered in the field. Actual APL samples from the landfill were used in the experiments. Key parameters were obtained from the experiments to conceptually design and cost the full-scale treatment system. This system will be carried into the associated feasibility study as the most appropriate alternative for treatment of the Midway APL.

Technologies and alternatives for treatment of the NAPL were not identified or evaluated. The NAPL is limited in volume and distribution, contains high levels of PCBs, and is easily separated from the APL (AGI 1990). Separation of the NAPL from the APL and its subsequent detoxification through offsite permitted incineration will continue to be the preferred methods of treatment at the Midway Landfill (Parametrix 1989).

1.4 OVERVIEW OF THE TREATABILITY STUDY REPORT

The treatability study report focuses on treatment of the APL from the Midway Landfill. The format of the report follows the guidance provided by the EPA for conducting remedial investigations and feasibility studies (EPA 1988). This report consists of six chapters.

Chapter 1, Introduction, provides background information on the site, and characterizes the leachate as a contributing source to groundwater contamination in the Midway Landfill area. Chapter 1 also discusses the characteristics of the landfill site as it relates to the generation of leachate, as well as the nature and extent of the leachate contamination.

Chapter 2, Remedial Technologies, establishes the remedial objectives and performance goals, and describes and evaluates the various remedial technologies and alternatives considered for treatment of the Midway leachate.

Chapter 3, Summary of the Treatability Study, summarizes the treatability studies that were performed as a further evaluation and screening process for those technologies and alternatives retained in Chapter 2. This summary discusses the technologies and alternatives that were chosen for evaluation in the laboratory, and the results and conclusions of the laboratory testing.

Chapter 4, Conceptual Design of the Alternatives, describes and conceptually designs the remedial alternatives developed, evaluated, and retained from the screening in Chapter 2 and the treatability studies in Chapter 3.

Chapter 5, Detailed Evaluation of Remedial Alternatives, evaluates each alternative with respect to protection of human health, compliance with cleanup standards, long-term effectiveness and permanence, reduction of toxicity, mobility, and volume of contaminants, short-term effectiveness, implementability, and cost.

Chapter 6, Summary and Selection of the Remedial Alternatives, summarizes the remedial alternatives based on the detailed evaluations and cost analyses performed in Chapter 5 and ranks them based on the degree to which they satisfy the evaluation criteria, and are cost-effective. From the summary and ranking, the recommended remedial alternative is selected for treatment of the Midway Landfill APL.

The appendices contain the laboratory reports prepared during the treatability studies. Included in these reports are laboratory observations, analytical results, and conclusions that document the progress of the studies and justify the selection of treatment technologies to be used as the Midway landfill leachate remedial alternatives.

1.5 SITE BACKGROUND

1.5.1 Site History

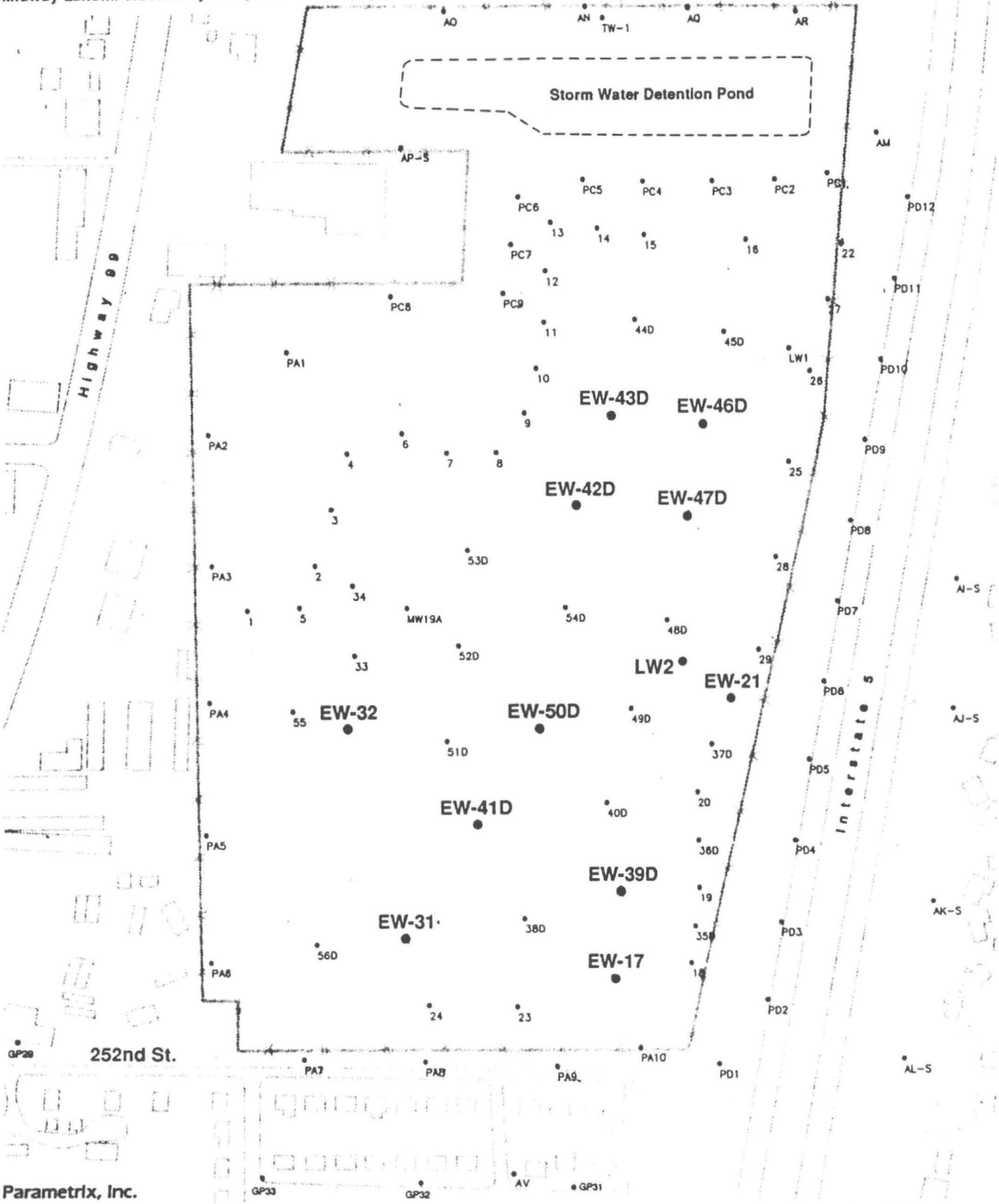
From 1945 to 1966, the site of the current Midway Landfill was operated as a gravel pit. The pit was originally located adjacent to a peat bog lake known as Lake Meade, located northeast of the center of the present landfill (Parametrix 1988). As the pit was mined, water was drawn from Lake Meade to wash silt and clay from the gravel and sand, and then returned to the lake. This silt and clay settled on the lake bottom. Near the end of the gravel pit operation, the lake drained into the southern end of the gravel pit, depositing a layer of clay and silt into the bottom of the pit. This layer of fine materials now underlies much, but not all, of the present landfill.

The Midway Landfill was created primarily to accept demolition materials, wood waste, and other nonputrescible materials. However, there is evidence that wastes other than demolition wastes were placed in the landfill. Records at Chemical Processors, Inc. (ChemPro) indicate that approximately two million gallons of industrial wastes were disposed of at the landfill from 1971 to 1980. Much of the material was hauled to the landfill in tanker trucks and disposed of as bulk liquids; the remainder was disposed of in drums. The composition and concentration of the materials are not specified in ChemPro's records, so it is not known whether the material would or would not have passed a screening process that was later used for low-level industrial waste accepted at the landfill. From 1980 to 1983, City records indicate that low levels of some industrial wastes, including paint sludges, dyes, preservatives for decorative plants, alkaline wastes, oily sludges, waste coolant, truck steam cleaning wastes, and some oily wastes were also deposited at the site. These low-level wastes were placed in the landfill only after they had passed a state-mandated screening process administered by the Seattle-King County Health Department.

1.5.2 Leachate Characteristics

Leachate at the Midway Landfill consists of two phases: nonaqueous and aqueous. The NAPL is an oily, viscous substance containing chlorobenzene, 1,2-dichloroethene, and elevated parts-per-million (ppm) concentrations of PCBs (AGI 1990). The NAPL has been found in limited volume in 12 onsite gas extraction wells located in the center portion of the landfill (Figure 1.2). In all 12 wells, the NAPL was found to be a layer floating on the APL. The NAPL is easily separated from the APL.

The Midway APL contains similar contaminants (in varying concentrations) to those found in the NAPL. However, the contaminant concentrations in the APL are several orders of magnitude less than those found in the NAPL (Table 1.1). The APL contains concentrations of volatile aromatic solvents (benzene, ethylbenzene, toluene, xylene, and chlorobenzene) at less than 1 ppm, ketones at up to 0.75 ppm, and 1,2-dichloroethene at up to 0.027 ppm. The leachate also contains polycyclic aromatic hydrocarbons and aliphatic hydrocarbons, phthalates, and phenols.



N

SCALE IN FEET

0 150 300

Fenced Site Boundary

• 23 Gas Probe, Gas Extraction Well, or Groundwater Monitoring Well Number and Location

● 17 Well with Detectable Thickness of Oil

Figure 1.2
Wells with Detectable Thicknesses of Oil

Table 1.1 Project summary of the Midway Landfill APL analytical data.

Parameter	Data from All APL Leachate Samples (Range)[a]	Data from Wells Sampled for the Treatability Study (Range)
Metals: (ppm)		
Arsenic	0.002 - 0.078	<0.002 - 0.023
Barium	NA	0.54 - 1.0
Cadmium	<.0004 - 0.034	<0.005
Chromium	<0.01 - 0.100	<0.01 - 0.04
Lead	<0.002 - 0.200	<0.003 - 0.36
Selenium	<0.002 - 0.024	<0.002
Silver	<0.01 - <0.05	<0.01 - 0.02
VOCs: (ppb)		
Benzene	4.0 - 15.00	<50
Ethylbenzene	<1.0 - 300	<50 - 170
Toluene	<1.0 - 62	<50
Xylenes	4.0 - 430	<50 - 210
Chlorinated ethanes (total)	<1 - 8.9	<50 - <500
Chlorinated ethenes (total)	<1 - 50	<5 - <50
Total Pesticides: (ppb)	<0.02 - <0.4	<0.050 - 0.12
Total PCBs: (ppb)	<0.5 - 280	<1.0 - 31.0
General Chemistry:		
pH	5.96 - 7.32	[b]
Conductivity (umhos)	2,160 - 12,950	[b]
TOC (ppm)	57.3 - 666	130 - 760
TOX (ppm)	0.42 - 110.9	0.82 - 11.0
BOD (ppm)	5.4 - 491.0	8.9 - 106.0
COD (ppm)	135.0 - 3,950	270 - 2,500
TDS (ppm)	120 - 6,040	2,300 - 7,200

[a] Range does not include data from FS round 2 (two-phase sampling dated 11-88), FS round 4 (treatability study samples), estimated values, or data from Analytical Resources Inc. (ARI).

[b] pH and conductivity will be added later.

NA = not analyzed

< = detection limit of the laboratory analysis.

PCBs have been detected in the APL at widely variable concentrations. APL from wells containing an oil phase often have PCB concentrations in the 1-part-per-million range. Samples from wells containing only APL have PCB concentrations at or below analytical detection limits of 1 part-per-billion (ppb). PCB concentrations of 1 ppm in the APL exceed the solubility of PCBs in water and are probably due to emulsified oil in the aqueous sample. Detectable levels of PCBs present in the APL and the NAPL have not migrated to the boundaries of the Midway Landfill.

The average dissolved and total concentration of priority pollutant metals in the APL are low. Iron and manganese in the APL are elevated. This is probably due to the anaerobic dissolution of these metals from the soils in the landfill. The leachate is well buffered with carbonate, and maintains a fairly constant pH of 7.0. Both the total organic carbon (TOC) and chemical oxygen demand (COD) are relatively low for landfill leachate and probably reflect the small amount of putrescible waste in the landfill. The APL has a moderate biological oxygen demand (BOD). The viscosity of the Midway APL appears identical to that of water. The APL contains fine particulate matter that forms a gray to black powdery residue on pumps and sampling equipment.

1.5.3 Leachate Volumes

An estimated 16-48 million gallons of contaminated leachate is present in the Midway Landfill (AGI 1990). The City of Seattle is currently installing a final cover over the landfill and has redirected the surface water drainage from Linda Heights to a new onsite detention pond. Assuming that all surface water inflow to the landfill ceases after the cover and the Linda Heights drainage improvements have been completed, the total water inflow to the landfill that could generate contaminated leachate is estimated to be 23 million gallons per year (gpy). This water inflow comes from shallow groundwater to the north and south of the site.

An estimated 220,000 gallons of NAPL are currently floating on the leachate water surface. Of this total volume, approximately 2,200 total gallons (1%) of the oil may be extractable from the landfill (AGI 1990a). This extractable volume of oil is the upper limit of what is expected to be encountered at the landfill. Although it is probable that less oil would be extractable from the site, this upper volume limit will be used for design and costing of the leachate treatment systems.

2. REMEDIAL TECHNOLOGIES

The purpose of this chapter is to (1) define the objectives for remedial action at the Midway Landfill and (2) establish the need and extent of remediation of APL from the site. The need and extent of remediation is based on federal and state environmental laws and regulations, the health risks associated with the landfill contaminants as identified in the EA Part 2, documented technological capabilities, and economic feasibility.

This chapter also identifies various remedial technologies that may be appropriate for treating the particular physical and chemical characteristics of the Midway APL. To identify those technologies specifically applicable to the Midway APL, an initial screening of the technologies is performed to identify those that are consistent with the remedial objectives and could be capable of attaining the performance goals. From the screened technologies, remedial alternatives can be developed for treatment of the Midway APL.

2.1 REMEDIAL OBJECTIVES

The primary objective for any remedial action at a hazardous waste site is to protect human health and the environment by eliminating or reducing the potential for exposure to contamination. The contaminants and pathways to human exposure are specific to each site. These site-specific elements, along with the associated risks, are identified in the EA.

Because there are no water wells that extract contaminated groundwater from the area of the Midway Landfill and the contaminated groundwater does not discharge to the land surface through springs or seeps, there are no current pathways of exposure to contaminants from the site. The remedial objectives for cleanup of contaminated leachate from the Midway Landfill are based on potential future exposure to the leachate contaminants through groundwater pathways. As discussed in the EA Part 2, two primary exposure pathways exist: ingestion of contaminated groundwater from a well, and inhalation of contaminants through showering with contaminated groundwater (Parametrix 1990a).

The remedial objectives established here will be used along with the performance goals identified in Section 2.3 to screen technologies potentially applicable to treatment of the Midway Landfill APL. Remedial technologies that do not illustrate the potential for achieving these standards will not be considered further.

The three primary objectives as they apply to treatment and disposal of the extracted Midway leachate are:

1. Protect human health and the environment from exposure to groundwater contamination by minimizing or reducing the migration of contaminated leachate from the landfill.

2. Attain or surpass federal or state mandated health-based cleanup standards.

3. Be compatible with the Midway site and its leachate characteristics and contaminants.

These objectives are listed in order of importance and are based on guidance from the *Handbook for Evaluating Remedial Action Technology Plans* (EPA 1983), the *National Oil and Hazardous Substances Pollution Contingency Plan* (CFR 1988), experience with other hazardous waste sites, and consultation with hazardous waste professionals. Cost was not considered to be an objective for the initial screening of remedial technologies. However, cost will be considered for the final screening of remedial alternatives.

The first objective is to minimize or reduce the potential for future exposure to the groundwater contaminants. This could be accomplished based on the assumption that leachate at the Midway Landfill will be extracted and treated for disposal. Removal of the leachate from the site will reduce or eliminate the leachate as a source of groundwater contamination associated with the Midway Landfill, and also protect the area's uncontaminated groundwater.

The second objective is to provide treatment of the leachate to an extent that complies with federal, state, or local cleanup standards. To determine remedial action cleanup standards for treatment of the Midway APL, it is necessary to determine the contaminants' potential impacts on human health. This potential impact can be assessed by comparing the chemical concentrations at or near the potential point of human exposure with applicable or relevant and appropriate federal, state, and local requirements (ARARs). This comparison will indicate the need and extent to which cleanup at the site should be performed. As noted in the EA Part 2, it should be emphasized that although the Midway Landfill has potential future exposure pathways to the contaminated leachate through the groundwater system, no current pathways exist (PMX 1990a).

For contaminants that have no ARARs, an endangerment assessment can be used to quantify the risk the contaminant poses to individuals. This assessment estimates the potential contaminant exposure concentrations and determines the amount of risk associated with that level of exposure. To protect human health and the environment, remedial action may be implemented when the chemical concentrations are greater than the ARARs or acceptable health-based standards quantified in the EA.

The third objective requires that the remedial action be compatible with the Midway site and its leachate characteristics and contaminants. This objective will aid in achieving the first two objectives. The following information must be considered when evaluating the feasibility and applicability of each of the proposed remedial technologies for treatment of the Midway APL:

- Leachate and Site Characteristics
  - The Midway leachate consists of an oily-viscous phase and an aqueous phase.
  - An estimated 23 million gpy of APL will be generated at the landfill and require treatment. The extraction rate of the leachate from the landfill is approximately 40 gallons per minute (gpm) (AGI 1990b).
  - Approximately 2,200 gallons of PCB-contaminated oil can be extracted from the site (AGI 1990a).
  - The APL as it is extracted from the landfill has a pH of approximately 7. The leachate is turbid to clear.
  - Permanent facilities for treatment, storage, and pumping of the leachate need to be located off the landfill surface because the landfill continues to settle.
- Leachate Contaminants
  - Leachate contaminants include metals, PCBs, and volatile organic compounds (VOCs).
  - The leachate has a high surfactant loading.
  - The leachate has a moderate BOD and COD.

2.2 ALTERNATIVES FOR DISPOSAL OF THE MIDWAY APL

The purpose of this section is to identify and evaluate alternatives for the disposal of treated Midway APL. The section describes the disposal alternatives, and screens them based on their feasibility for implementation. Once the most feasible disposal alternative has been determined, the appropriate ARARs can be identified and the extent to which treatment of the Midway APL must be performed can be established.

Several alternatives exist for disposal of the Midway APL after treatment has been performed. These alternatives, briefly discussed below and summarized in Table 2.1, include:

1. Disposal through reinjection into the landfill.
2. Disposal to a surface water body through the onsite detention pond.
3. Disposal to the Municipality of Metropolitan Seattle (Metro) sanitary sewer system.
4. Disposal to the Des Moines Sewer District system.

2.2.1 Disposal through Reinjection into the Landfill

This disposal option involves reinjection of the treated APL through a series of deep-well holes across the surface of the Midway Landfill. This reinjection would assist in leaching contaminants from the refuse and would increase the overall rate at which the landfill decomposed. However, because of the complex hydrogeologic conditions at the landfill, it would be difficult to design an extraction/reinjection system that could efficiently and fully extract the leachate from the landfill. Leachate that bypassed the extraction system could continue to contribute to groundwater contamination. This option would conflict with the remedial objective of protecting human health and the environment by reducing or eliminating the leachate from the site. Also, installation of the various reinjection wells could compromise the integrity of the landfill cover, causing additional infiltration of water into the refuse. Again, this infiltration could contribute to the groundwater contamination at Midway through generation of contaminated leachate. Disposal of the treated Midway APL through reinjection into the landfill is not a viable alternative.

2.2.2 Disposal to a Surface Water Body through the Onsite Detention Pond

This option involves disposal of the treated Midway leachate to McSorley Creek (formerly Smith Creek) through the onsite detention pond. In order to discharge to McSorley Creek (Smith Creek), the treated leachate will have to attain surface or drinking water quality standards. Although achievement of these standards is possible, institutional considerations would likely restrict this type of disposal alternative. Also, to prevent damaging erosion of McSorley Creek (Smith Creek), the volume of water discharged from the detention pond could not be increased beyond its current level. During times of heavy precipitation and runon, it is probable that the leachate treatment system would have to be shut down in order to assure the pond does not exceed its holding capacity or its discharge limits to the creek. During this time of inoperation, contaminated leachate from the Midway Landfill could enter the groundwater system. Disposal of the treated Midway APL to McSorley Creek (Smith Creek) through the detention pond is not a viable alternative.

2.2.3 Disposal to the Metro Sanitary Sewer System

This disposal alternative involves pretreating the Midway APL to an extent that satisfies the Metro standards for discharge to their sewer system. Metro would provide additional treatment of the Midway effluent before it is ultimately discharged to the environment in compliance with its National Pollutant Discharge Elimination System (NPDES) permit. Metro currently has the capacity and the appropriate biological and chemical processes available to treat the Midway effluent. Disposal of the treated Midway APL to Metro is a viable disposal alternative. However, it is not the preferred alternative because the sewer is approximately three miles from the landfill.

2.2.4 Disposal to the Des Moines Sewer District System

This disposal alternative involves pretreating the Midway APL and discharging it to the Des Moines sanitary sewer system. Metro pretreatment standards will be used to guide the selection of acceptable treatment technologies. The Des Moines system would provide additional treatment of the Midway effluent before it is discharged to the environment in compliance with its NPDES permit. Disposal of the treated Midway APL to the Des Moines system is a preferred alternative because of the proximity of the system to the landfill.

Table 2.1. Summary of disposal alternatives for the treated Midway APL.

Disposal Alternative	Restrictions
Landfill Reinjection	No assurance that newly generated leachate could be fully collected. Reinjection could compromise the integrity of the landfill cover. May not reduce or eliminate leachate as a contributing source of groundwater contamination.
McSorley Creek (Smith Creek) through Pond	May have to stop leachate extraction and treatment during times of heavy precipitation and runon into the pond to maintain discharge limits to McSorley Creek (Smith Creek). Would have to satisfy stringent ambient water quality standards.
Metro Sanitary Sewer	Would have to satisfy pretreatment requirements.
Des Moines Sanitary Sewer	Would have to satisfy pretreatment requirements.

2.3 REMEDIAL ACTION PERFORMANCE GOALS

The ARAR that will determine the extent to which the Midway APL will be treated will be based on the Metro pretreatment standards. The goal of the APL treatment process at Midway will be to produce an effluent of suitable quality for discharge to the Des Moines system. Des Moines will provide additional treatment of the Midway liquid before it is ultimately discharged to the environment in compliance with its NPDES permit.

In order to satisfy the standards for discharge to Des Moines, the leachate must be pretreated to reduce free oil, VOCs, PCBs, and possibly heavy metals and other compounds. There will be no onsite treatment of the NAPL. NAPL from the landfill will be separated from the APL and incinerated at an offsite permitted facility as a *Toxic Substances Control Act* (TSCA) waste (PMX 1989).

Pretreatment levels required for discharge to a Des Moines sewer line are not precisely defined for all contaminants in landfill leachate. Nevertheless, preliminary goals were established to screen the various treatment technologies and measure the relative effectiveness of different treatment alternatives during the laboratory studies. These goals were developed based on Metro standards (Metro 1990), a review of permits for the discharge of surface water from Midway and pretreated leachate from the Kent Highlands Landfill to Metro, and standards for the Cedar Hills Landfill and Western Processing facility.

The following are the preliminary goals developed for the pretreatment of contaminants present in the Midway APL:

- PCBs: 0.5 mg/L
- VOCs: 10 μg/L
- Arsenic: 1.0 mg/L
- Cadmium: 0.5 mg/L
- Chromium: 2.75 mg/L
- Copper: 2.0 mg/L
- Lead: 1.0 mg/L
- Nickel: 2.0 mg/L
- Fats, oils, and grease: 100 mg/L.

The pretreatment goal specified above for PCBs is Metro's current standard for treated waste from a local hazardous waste treatment, storage, and disposal facility. The goal for VOCs is based on a working knowledge of treatment technologies and their ability to achieve cleanup levels when implementation and maintenance costs are considered. The pretreatment goals for metals and fats, oils, and grease (FOG) are the maximum limits specified by Metro pretreatment standards for discharge into their sanitary sewer system (Metro 1990). Technologies that cannot attain the goals listed above will not be considered for leachate remediation at Midway. The extent to which the concentration of other contaminants in the APL are reduced will be determined through bench-scale testing and analysis of the remedial technologies and alternatives (Chapter 3).

2.4 IDENTIFICATION AND INITIAL SCREENING OF THE REMEDIAL TECHNOLOGIES

This section identifies the treatment technologies applicable to most hazardous waste sites. The goal of this section is to identify those technologies specifically applicable to the Midway Landfill that can be combined to form treatment alternatives.

Technologies that remedy groundwater and leachate contamination at hazardous waste sites are presented in Table 2.2. This list was developed from the *Handbook of Remedial Action at Waste Disposal Sites* (EPA 1985), the *Handbook for Evaluating Remedial Action Technology Plans* (EPA 1983), *A Handbook on Treatment of Hazardous Waste Leachate* (EPA 1987), and experience with other hazardous waste projects and technologies.

Table 2.2. Potential treatment technologies for cleanup of contaminated APL at the Midway Landfill.

<u>Biological</u>:

Activated sludge
Aeration lagoon

<u>Chemical</u>:

Ion exchange
Oxidation (for example ozone or ferric chloride)
Photo-oxidation (for example O_2/UV, O_3/UV, or H_2O_2/UV)
Flocculation/sedimentation

<u>Physical</u>:

Activated carbon adsorption
Aeration/air stripping
Froth flotation/dissolved air flotation
Oil/water separation
Reverse osmosis
Filtration
Ultrafiltration

2.4.1 Initial Screening Criteria

As stated before, the objective of any remedial technology is to protect human health and the environment from exposure to contaminants. Care must be taken to select technologies appropriate for the Midway Landfill's site characteristics and contaminants. Technologies that offer a permanent means of reducing or eliminating the potential for pathways of exposure and can be performed onsite are preferred.

The treatment technologies listed in Table 2.2 represent general remedial actions for many hazardous waste sites. To provide a more focused list of actions specific to the problems at the Midway Landfill, an initial screening was done based on the objectives listed in Section 2.1. Again, cost was not considered in this initial screening of remedial technologies, but will be discussed in Chapter 5.

The following section discusses the screening of these technologies to determine those that may be useful for remediation of leachate contamination at the Midway Landfill. Technologies with performance characteristics that are consistent with the remedial objectives and compatible with site and waste characteristics will be retained for further evaluation. These technologies will be combined to form treatment alternatives for the cleanup of specific contaminants or groups of contaminants at the site (Section 2.5).

2.4.2 <u>Results of Screening</u>

There are three categories of technologies outlined for aqueous phase treatment: biological, chemical, and physical. Of these three categories, only chemical and physical treatments can be applied to the leachate at the Midway Landfill. Interference from certain contaminants (metals and suspended solids) and the slowness with which certain compounds are degraded (halogenated hydrocarbons) removed the biological treatment category from consideration. Also, there is no need to biologically treat the leachate because it is going to the Des Moines sanitary sewer, which already has biological treatment.

This section describes the technologies listed in Table 2.2 and presents the results of the initial screening based on the objectives listed in Section 2.1.

2.4.2.1 Chemical Treatment Technologies

Chemical treatment technologies destroy or change the aqueous phase contaminants into less toxic or more easily removed compounds.

Ion Exchange

Ion exchange is a process whereby toxic ions are removed from the aqueous phase by exchanging them with relatively harmless ions held by the ion exchange material (resin). The ion exchange resin has the ability to exchange either positively charged ions or negatively charged ions. Ion exchange is used to remove a broad range of ionic species from water, including soluble metals, halides, sulfates, nitrates, phenols, and amines. This technology is used primarily for the removal of dissolved ionic species when a high-quality effluent is required.

The exchange reaction is reversible and depends on the concentration of ions. It is also possible to regenerate the exchange resins for reuse. However, consideration must be given to disposal of the contaminated ion exchange regeneration solution. Another important operational consideration is the selection of regeneration chemicals. Also, the reliability of ion exchange is markedly affected by the presence of suspended solids.

Ion exchange is an established technology for removal of heavy metals and hazardous anions from dilute solutions. Ion exchange systems are relatively compact and commercially available. Although this process is easy to control and results in extremely pure water, ion exchange is relatively expensive. Because solids and organics will foul the resins, the use of this process in treating the leachate is probably limited to a final polishing stage, in which effluent is discharged to sensitive surface waters. In addition, metals in the Midway APL are not at high levels and other technologies will further reduce the metals. Therefore, ion exchange will not be tested in the treatability study.

Chemical Oxidation

Chemical oxidation involves the addition of an oxidizing agent to the leachate at controlled pH. Both organics and inorganics are oxidized. The oxidation process can render the contaminant nonhazardous, convert the compound to a more degradable form, or convert the compound into a more toxic or mobile form. Chemical oxidation is usually used to treat water that contains iron and manganese or low levels of organic compounds. It is not usually used as the primary treatment process for complex waste streams because of the difficulties of controlling the final products of the oxidation.

The effectiveness of chemical oxidation for a specific compound is a function of the concentration of the compound, the concentration of the oxidant, the reaction or residence time, the presence of other oxidizable chemicals in the waste stream, and the type of chemical oxidant used. Ozone (O_3) and hydrogen peroxide (H_2O_2) are the most common chemical oxidants because they break down to oxygen and water. Ozone is acutely toxic and corrosive and requires considerable health and safety monitoring, but can be generated in-situ. Hydrogen peroxide is somewhat more stable and easier to work with; it can be generated onsite or transported to the site as an aqueous solution. Both reagents are costly.

Chemical oxidation with hydrogen peroxide or ozone is attractive because the process does not require the addition of anything to the wastewater but H_2O_2 or O_3. In addition, hydrogen peroxide is environmentally safe as it breaks down into oxygen and water.

Chemical oxidation reactions can be carried out using simple, readily available equipment. However, implementation is complicated because every reaction system must be designed for the specific application. Chemical oxidation is used primarily for detoxification of cyanide and treatment of dilute waste streams containing oxidizable organics. This process is not suited for treating complex waste streams. Chemical oxidation has not been widely used in treating hazardous waste streams. Chemical oxidation will only be considered in the treatability study when combined with photolysis (photo-oxidation) for a final polishing step for the removal of organics.

Photo-oxidation

Photo-oxidation uses a chemical oxidant such as hydrogen peroxide in conjunction with ultraviolet (UV) light to break down organic compounds to carbon dioxide and water. This process breaks down organics more efficiently and completely than oxidation alone. Wastewater is passed through a chamber and mixed with hydrogen peroxide. The mixture is then irradiated with high-energy ultraviolet light. The process is capable of oxidizing virtually any organic compound under the proper conditions. However, because this method is non-selective, all organic compounds present will be attacked. Also, this process works best when treating dilute solutions because the UV light is blocked by turbid solutions. As a result, peroxide/UV will be tested, if necessary, in Phase II as a secondary treatment step after the bulk of the organic compounds have been removed in a primary treatment step.

Flocculation/Sedimentation

Flocculation is the process by which small, unsettleable particles suspended in a liquid medium are made to agglomerate into larger, more removable particles. Flocculation facilitates the removal of contaminants from the liquid phase by sedimentation and/or filtration. Sedimentation is frequently included in leachate treatment process trains to separate solids generated by chemical processes.

Typical flocculants include inorganic chemicals such as aluminum sulfate (alum), lime, and iron salts (ferric chloride and ferrous sulfate). In addition, high molecular weight organic polyelectrolytes (polymers) can be used alone or in conjunction with the flocculants to form a more dense floc. These flocculants and polymers work by neutralizing charged colloidal and suspended materials, allowing them to agglomerate.

Flocculation/sedimentation can be applied in the removal of most metals (arsenic, cadmium, chromium (III), copper, iron, lead, mercury, nickel, and zinc), suspended solids, total dissolved solids, oil, grease, and PCBs from wastewater. This process can be used in most aqueous waste streams. However, certain physical or chemical characteristics can impose limitations on the process. For instance, inorganic and organic ligands in the wastewater may complex with the metals, making treatment by flocculation less efficient.

There are two major drawbacks to flocculation/sedimentation. First, it is a nondestructive process that generates sludge. Second, this sludge would have to be dewatered and disposed of, possibly at a hazardous waste facility.

Flocculation/sedimentation is a well-established technology with well-defined operating parameters. The equipment is readily available and easy to operate. The performance and reliability of the process depends greatly on the variability of the composition of the waste being treated. However, there are no contaminant concentration limits (upper or lower) for this technology. Flocculation/sedimentation provides a well-documented and reliable method for removal of many contaminants. Consequently, this treatment technology will be tested in Phase I of the treatability study.

2.4.2.2 Physical Treatment Technologies

The technologies in this category treat the contaminated aqueous solution by physically separating the contaminants, generally by phase separation (separating vapors, liquids, and solids) or filtration.

Activated Carbon Adsorption

Activated carbon removes dissolved contaminants from leachate by adsorption onto the carbon surface. The treatment is conducted by passing leachate through a vessel packed with activated carbon. PCBs and VOCs generally adsorb well to the carbon. While different types of activated carbon can be used that preferentially adsorb a specific group of chemicals, other compounds in the water can cause the activated carbon to be less effective in adsorbing the chemicals of concern.

Periodically, the activated carbon becomes saturated with contaminants and must be removed and regenerated or replaced. The carbon can be regenerated by thermally or chemically removing adsorbed materials. Pretreatment of the leachate would be required because of the oil and grease and suspended solids in the Midway leachate.

Activated carbon adsorption has been used successfully for water treatment for over 20 years. The volatile organic chemicals contained in the Midway Landfill leachate would be amenable to activated carbon treatment. However, since large amounts of carbon would be needed with the initial COD levels, carbon adsorption will be considered further as a secondary treatment technology (Phase II) for polishing of the effluent from a primary treatment technology (Phase I).

Aeration/Air Stripping

Aeration is used to remove volatile organic compounds from aqueous wastestreams. This technology consists of transferring volatile contaminants from the liquid phase to the gas phase. By increasing the liquid-gas interface area, more volatile contaminants are transferred. There are two methods typically used for increasing the liquid gas interface: (1) passing air through a basin of wastewater (an aeration basin), and (2) simultaneously passing water down and air up through a tower packed with a water-diffusing media (packed tower). Each of these methods has a possible application for the Midway leachate. Because the high BOD, TSS, and iron in the leachate could cause biological and physical clogging of a packed tower, and because the surfactants in the leachate will produce moderate volumes of foam, an aeration basin may work best.

Initial review of the organic chemicals contained in the Midway leachate suggest that air stripping would be an effective removal technology. To control VOC emissions, the off-gas could be collected and sent to the onsite flares for incineration. Aeration would be effective for all volatile organic compounds of concern. Also, given the relatively high temperature (>23.4° C) of the leachate, the semivolatile compounds may also be removed with the volatile organic compounds. As a result, aeration will be studied as a secondary treatment technology during Phase II of the treatability study.

Froth Flotation/Dissolved Air Flotation

Froth flotation is a method of removing fine particulates, surfactants, oils, and dissolved chemicals from water by sorbing the materials onto a foam or froth that rises to the surface of a tank or column of water. Dissolved metals may also be removed in the form of metal oxides and hydroxides. The water is vigorously aerated from the base of the tank. The resulting foam is then skimmed from the top of the tank and treated separately.

A foaming agent may be added to the solution by a process operator or it may already be present in the wastewater. By selecting either cationic, anionic, or neutral foaming agents, it is possible to remove specified chemicals from the solution and control the amount of liquid in the foam.

Froth flotation will be tested as a primary treatment technology in Phase I of the treatability study. The principal goal of the froth flotation process will be to remove or reduce the concentration of PCBs in the leachate solution.

Oil/Water Separation

Oil/water separation is used to separate immiscible organic compounds such as PCB oils from leachate. Oil/water separation simply involves allowing the oil phase to separate from the aqueous phase in a holding tank and then skimming off the oil phase. A limited amount of oil is present in the Midway leachate. Oil interferes with most of the treatment technologies discussed in this section. Therefore, it will be necessary to include oil/water separation in the final treatment string. Oil/water separation will be tested during Phase I of the treatability study.

Reverse Osmosis

Osmosis is the flow of water (or other solvent) from a dilute solution to a more concentrated solution through a semipermeable membrane. Reverse osmosis is a process that uses pressure to reverse the normal osmotic flow of liquid. Pressure is applied to the concentrated solution to force the flow of water through the membrane and into the dilute solution. As a result, the concentration of impurities is built up on one side of the system, while relatively clean water is released on the other side.

Reverse osmosis systems are susceptible to chemicals, fouling, and plugging. Wastewater must be pretreated to remove oxidizers (for example iron), particulates, oil, and grease. In addition, reverse osmosis will not reliably treat waste with a high concentration of organic compounds. Therefore, this technology is primarily used as a polishing step to treat low flow waste streams. Reverse osmosis will not be considered further.

Filtration

Filtration is a technology that removes suspended solids from solution by forcing the fluid through a porous medium. The filter media is typically sand or sand with coal. These types of filters are usually used in treating waste streams containing less than 200 mg/L (200 ppm) of suspended solids. Higher suspended solids loads will mean excessively frequent backwashing. The backwash solution could contain high concentrations of solids and possibly require treatment. Filtration is a reliable technology for removing low levels of solids. However, colloidal size particles are not effectively removed. Filtration will not be considered further as a viable treatment technology.

Ultrafiltration

Ultrafiltration is a process using a semipermeable membrane to remove particulates or high molecular weight compounds from wastewater. Wastewater or leachate is pressurized and forced through a filter with small pores, taking low molecular weight compounds with it. Contaminants and particulates are concentrated as the wastewater is recirculated through the filter. A concentrated liquid is produced that must be processed and treated further. Compounds are not removed if they are dissolved and of low molecular weight.

Ultrafiltration can be applied to the removal of metals, semivolatile organics, pesticides, and PCBs. However, this technology has not yet been applied to the full-scale treatment of hazardous waste leachate. Also, the suspended and dissolved solids in the Midway leachate would quickly clog the filter. Therefore, this technology would be more useful in a secondary treatment polishing step than a primary treatment step. Ultrafiltration will be studied further, if necessary, in Phase II of the treatability study.

2.4.3 Summary of Screening

The results of the screening of technologies performed in this section are summarized in Table 2.3. This table identifies the technologies that will be retained and used in Section 2.5 in the development of treatment alternatives for the Midway leachate. This table also identifies the technologies that were eliminated from further consideration.

Table 2.3. Summary of the screening of potential treatment technologies for cleanup of the contaminated APL at the Midway Landfill.

Technology	Retained for Development of Remedial Alternatives	Eliminated from Further Consideration
Biological:		
Activated sludge		X
Aeration lagoon		X
Chemical:		
Ion exchange		X
Oxidation		X
Photo-oxidation	Phase II	
Flocculation/sedimentation	Phase I	
Physical:		
Activated carbon adsorption	Phase II	
Aeration/air stripping	Phase II	
Froth flotation/dissolved air flotation	Phase I	
Oil/water separation	Phase I	
Reverse osmosis		X
Filtration		X
Ultrafiltration	Phase II	

2.5 DEVELOPMENT AND INITIAL SCREENING OF REMEDIAL ALTERNATIVES

The purpose of this section is to identify and evaluate preliminary remedial alternatives for the pretreatment of the Midway Landfill APL. The alternatives identified here are constructed from the technologies remaining from the screening process performed in Section 2.4. This section describes the technologies comprising each alternative, and qualitatively screens the alternatives based on their effectiveness in protecting human health and the environment. Cost was not considered an important element of the initial screening process. Cost will be considered when the alternatives are developed in more detail in Chapter 4. The purpose of the initial screening of the alternatives was to identify those that exhibited sufficient merit to undergo detailed evaluation in bench-scale testing (Chapter 3).

Federal guidance exists for the development of remedial alternatives for feasibility studies. This guidance, required by CERCLA and the federal *Clean Water Act* (CWA), is provided in the *National Oil and Hazardous Substances Pollution Contingency Plan* (NCP) (CFR 1988). The NCP requires a feasibility study to develop the following remedial alternatives:

- A no-action alternative
- An alternative for treatment or disposal at an offsite facility
- An alternative that attains federal and state applicable or relevant and appropriate requirements (ARARs) for cleanup of contamination
- An alternative that exceeds the ARARs
- An alternative that does not attain the ARARs.

The no-action alternative and alternative for treatment or disposal at an offsite facility will be discussed in the associated feasibility study. The treatability study assumes leachate will be extracted from the landfill and treated onsite for disposal. The associated feasibility study will also identify available options for extraction of the leachate from the landfill and reduction of the leachate volume, as well as the transportation of the effluent from the onsite pretreatment process to the publicly owned treatment works (POTW).

2.5.1 Development of Remedial Alternatives

Before remedial alternatives were developed for the pretreatment of the Midway APL, specific remedial objectives were defined. The objectives developed in Section 2.1 for the screening of remedial technologies also apply for the development of remedial alternatives. These objectives, with the exception of Objective 3, are restated here:

1. Protect human health and the environment from exposure to groundwater contamination by minimizing or reducing the migration of contaminated leachate from the landfill.

2. Attain or surpass federal or state mandated health-based cleanup standards.

As previously identified in Section 2.1, Objective 3 required remediation to "be compatible with the Midway site and its leachate characteristics and contaminants." Because the technologies retained after screening in Section 2.4 are compatible with site and waste characteristics at the Midway Landfill, alternatives developed from these technologies would also be compatible. These alternatives therefore satisfy Objective 3.

As previously stated, the cleanup standards for the Midway APL are based on pretreatment requirements specified by Metro for discharge to the Des Moines sewer system.

2.5.2 Description and Evaluation of Preliminary Remedial Alternatives

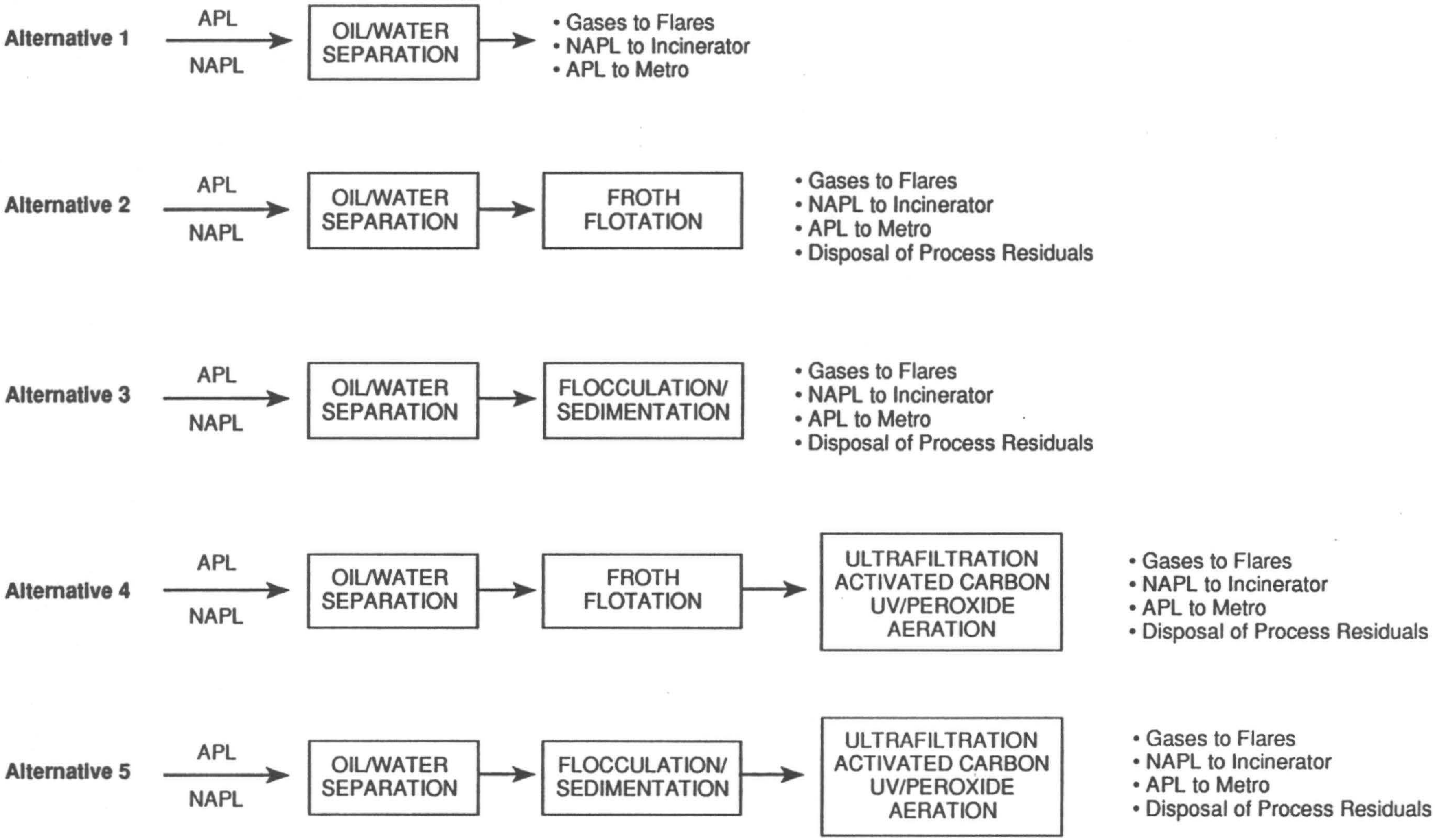
The remedial alternatives for pretreatment of the Midway APL are listed in Table 2.4 and illustrated in Figure 2.1. Because of the variability of the contaminant concentrations in landfill leachate, these alternatives encompass a wide range of potential pretreatment methods for the Midway APL. The actual extent of pretreatment necessary, and therefore the alternative that satisfies the Metro pretreatment standards, will be determined based on results from the treatability study using actual samples of APL from the landfill (Chapter 3).

The alternatives listed in Table 2.4 all have common health risk effects. Each alternative would minimize or reduce the potential health risk from the contaminated APL through the leachate/groundwater pathway of exposure. Workers operating the process could be exposed to the contaminants. However, the conditions could be controlled to minimize exposure. Because the APL would attain the Metro pretreatment standards, the alternatives would pose no additional health risk to the Des Moines workers. PCB-contaminated oil would be handled under controlled conditions, then permanently destroyed through incineration. Volatile gases and stripped volatile organics from the processing operations would be collected, contained, and incinerated in the existing permitted landfill flares.

Each alternative satisfies Objective 1 listed in Section 2.5.1.

Table 2.4. Remedial alternatives for pretreatment of the Midway APL.

Alternative 1:	Oil/water separation; collection and onsite incineration of volatile gases; collection and transportation of NAPL to permitted incinerator; discharge of the APL to Des Moines.
Alternative 2:	Oil/water separation in combination with froth flotation; collection and onsite incineration of volatile gases and stripped volatile organics; collection and transportation of NAPL to permitted incinerator; discharge of the pretreated APL to Des Moines; disposal of process residuals.
Alternative 3:	Oil/water separation in combination with flocculation/sedimentation; collection and onsite incineration of volatile gases and stripped volatile organics; collection and transportation of NAPL to permitted incinerator; discharge of the pretreated APL to Des Moines; disposal of process residuals.
Alternative 4:	Oil/water separation in combination with froth flotation; polishing of the aqueous effluent with ultrafiltration, granular activated carbon, UV/peroxide, and/or aeration; collection and onsite incineration of volatile gases and stripped volatile organics; collection and transportation of NAPL to permitted incinerator; discharge of the pretreated APL to Des Moines; disposal of process residuals.
Alternative 5:	Oil/water separation in combination with flocculation/sedimentation; polishing of the aqueous effluent with ultrafiltration, granular activated carbon, UV/peroxide, and/or aeration; collection and onsite incineration of volatile gases and stripped volatile organics; collection and transportation of NAPL to permitted incinerator; discharge of the pretreated APL to Des Moines; disposal of process residuals.



Process Residuals = Foam, Sludge

Figure 2.1
Illustration of Pretreatment Alternatives

Because the technologies comprising each alternative have been discussed in detail in Section 2.4, no further discussion is provided here. However, the alternatives are discussed in sufficient detail to provide a qualitative evaluation of the degree to which the alternatives could attain the Metro pretreatment standards.

2.5.2.1 Alternative 1

Description

This alternative involves separating the NAPL from the APL and discharging the APL to the Des Moines sanitary sewer system through the pipeline located along the east side of State Route 99 (SR-99). Des Moines would further treat the APL before the effluent is discharged to a surface water body in compliance with their NPDES permit. Volatile gases from the separation unit would be collected and incinerated in the existing permitted landfill flares. The NAPL would be disposed of at an offsite, permitted incineration facility.

Effectiveness

Alternative 1 would provide the simplest onsite pretreatment of the Midway APL. This alternative would be most appropriate if the APL contained low concentrations of contaminants where no further pretreatment would be necessary to attain the Metro standards (see Section 2.3).

2.5.2.2 Alternative 2

Description

This alternative involves separating the NAPL from the APL and pretreating the APL by froth flotation. Froth flotation involves vigorous aeration of the leachate to generate a foam. The foam could contain fine particulates, surfactants, oils, PCBs, and dissolved solids from the APL. Some metals may be removed from solution in the form of colloidal iron. Foaming agents could be added to remove specific chemicals from the solution and control the amount of liquid in the foam.

The foam would be skimmed from the surface, collapsed, and dewatered. The solids would be dewatered, designated, and disposed of at an appropriate, permitted landfill. The liquid phase would be returned to the APL pretreatment system.

The effluent from the APL pretreatment process would be discharged to Des Moines for further treatment. Volatile gases and stripped volatile organics from the pretreatment units would be collected and incinerated in the existing permitted landfill flares. The NAPL would be disposed of at an offsite, permitted incineration facility.

Effectiveness

Alternative 2 would provide additional pretreatment of the Midway APL beyond oil/water separation in order to attain the Metro standards. This alternative would focus on reducing the concentration of PCBs and organic contaminants. The concentration of metals and other contaminants may also be reduced.

2.5.2.3 Alternative 3

Description

This alternative involves separating the NAPL from the APL and pretreating the APL by flocculation/sedimentation. Flocculation/sedimentation involves adding chemicals to the leachate to transform dissolved contaminants into insoluble precipitates. After flocculation, the wastewater would flow through a clarifier where the precipitate would settle. This precipitate would be separately treated and disposed of. The effluent from the pretreatment process would be discharged to Des Moines for further treatment. Volatile gases and stripped volatile organics from the pretreatment units would be collected and incinerated in the existing permitted landfill flares. The NAPL would be disposed of at an offsite, permitted incineration facility.

Effectiveness

Similar to Alternative 2, this alternative would provide additional pretreatment of the Midway APL beyond oil/water separation in order to attain the Metro standards. This alternative would focus on reducing the concentration of PCBs and metals in the APL. The concentration of organics and other contaminants may also be reduced.

2.5.2.4 Alternative 4

Description

This alternative involves separating the NAPL from the APL and pretreating the APL by froth flotation as described in Alternative 2. The resulting foam, solids, and liquid from the pretreatment and dewatering processes would be treated and disposed of as described in Alternative 2. The effluent from the froth process would be further treated by one or more technologies, including ultrafiltration, activated carbon, UV/peroxide, and aeration. The effluent would then be discharged to Des Moines for additional treatment. Volatile gases and stripped volatile organics from the pretreatment units would be collected and incinerated in the existing permitted landfill flares. The NAPL would be disposed of at an offsite, permitted incineration facility.

Effectiveness

Alternative 4 would provide the most extensive pretreatment of the Midway APL to attain the Metro standards. This alternative focuses on reducing the levels of oils, VOCs, and PCBs. Alternative 4 would apply to Midway APL that contains elevated concentrations of contaminants that could not be sufficiently reduced in Alternative 2 to levels that would be acceptable to Des Moines.

2.5.2.5 Alternative 5

Description

This alternative involves separating the NAPL from the APL and pretreating the APL by flocculation/sedimentation as described in Alternative 3. After flocculation, the wastewater would flow through a clarifier where the precipitate would settle. This precipitate would be separately treated and disposed of. The effluent from the flocculation process would be further treated by one or more technologies, including ultrafiltration, activated carbon, UV/peroxide, and aeration. The effluent would then be discharged to Des Moines for further treatment. Volatile gases and stripped volatile organics from the pretreatment units would be collected and incinerated in the existing permitted landfill flares. The NAPL would be disposed of at an offsite, permitted incineration facility.

Effectiveness

Similar to Alternative 4, this alternative would provide the most extensive pretreatment of the Midway APL to attain the Metro standards. This alternative, however, focuses on reducing the levels of metals and suspended and dissolved solids. APL that would be appropriate for this alternative would have high contaminant concentrations that could not be sufficiently reduced in Alternative 3 to attain the Metro standards.

2.5.3 Summary of Remedial Alternatives

The remedial alternatives for pretreatment of the Midway APL are summarized in Table 2.5. All of the alternatives have been retained for further detailed evaluation in the treatability study.

Further screening of the alternatives is provided in Chapter 3. A detailed evaluation of the alternatives retained after the treatability study was performed and is provided in Chapter 4. The evaluations performed here and in Chapters 3 and 4 will determine the alternative most appropriate for treating the Midway APL.

Table 2.5. Summary of the remedial alternatives for pretreatment of the Midway APL.

Alternative	Application
1	Simplest onsite processing. Would apply to APL that contains low concentrations of contaminants.
2	Additional pretreatment of the APL beyond oil/water separation. Focuses on reducing the concentration of PCBs and organic contaminants. May also reduce the concentration of metals and other contaminants.
3	Additional pretreatment of the APL beyond oil/water separation. Focuses on reducing the concentration of PCBs and metals. May also reduce the concentration of organics and other contaminants.
4	Provides the most extensive pretreatment of the APL to attain Metro standards. Focuses on reducing oils, VOCs, and PCBs. Applies to Midway APL that contains elevated concentrations of contaminants that could not be reduced sufficiently in Alternative 2 to attain the Metro standards.
5	Similar to Alternative 4. Provides the most extensive amount of pretreatment of the APL to attain Metro standards. Focuses on reducing metals and suspended and dissolved solids. Applies to Midway APL that contains elevated concentrations of contaminants that could not be reduced sufficiently in Alternative 3 to attain the Metro standards.

3. SUMMARY OF THE TREATABILITY STUDY

3.1 INTRODUCTION

The purpose of the *Midway Landfill Feasibility Study Treatability Study* was to identify a technology or group of technologies that could treat the APL to a level that would meet or surpass the Metro pretreatment standards for discharge to the Des Moines sewer system.

Identification of the appropriate treatment technologies required conducting experiments under conditions that were characteristic of actual processing conditions. From these experiments, key design parameters for estimating the costs of full-scale systems were obtained.

No attempt was made during the treatability study to optimize the technologies or processes being tested. This optimization will be performed during future pilot-scale studies as necessary.

Several treatment technologies were identified in the screening process in Section 2.4. However, only three were tested in the treatability study. These technologies include:

- Oil/water separation
- Flocculation/sedimentation
- Froth flotation/dissolved air flotation

A limited amount of oil is present in the leachate and free oil may interfere with the other treatment technologies. Therefore, oil/water separation must be the first step in treatment of the Midway APL. Flocculation and froth flotation were believed to be the only technologies from the above list potentially capable of attaining the Metro pretreatment levels without further processing. Technologies such as activated carbon and ultrafiltration were believed to be applicable to the leachate only as polishing steps. The differences between the technologies required a phased approach to the treatability study.

3.2 STUDY PHASES

The initial phase of the treatability study (Qualitative Phase) was designed to qualitatively evaluate the characteristics of the leachate under processing conditions. The leachate was subjected to frothing, aeration, and flocculating conditions and agents to determine if these technologies are potentially capable of treating leachate at the landfill.

Phase I of the study quantitatively evaluated oil/water separation, flocculation/-sedimentation, and froth flotation processes for application to the leachate. Various processing conditions were simulated, and samples taken and analyzed to determine which of these technologies could attain or surpass the Metro pretreatment levels. Analytical results determined which process was most effective in reducing contaminant concentrations, and whether additional processing was required.

Phase II, if necessary, would have involved polishing effluent from Phase I with activated carbon, aeration, UV/peroxide, or ultrafiltration processes. Again, samples would have been collected and analyzed to determine the extent to which contaminant concentrations had been reduced. A treatment process that effectively satisfied or surpassed the treatment levels would then have been identified. However, Phase II was not needed and not performed (see Section 3.5.4).

Once the treatment process was identified, Phase III involved processing leachate through the system in triplicate to determine the variability of the effluent quality. This final treatment process was conceptually designed and costed, and was considered the most applicable treatment process for the APL at the Midway Landfill throughout the associated FS. Each phase of the treatability study is described in further detail below.

Analysis of the treatability study samples was performed by two laboratories. Phase I samples were analyzed by the Enviros Corporation. A quick turnaround time was the most important factor during the Phase I tests. Therefore, detection limits for chlorinated organics were much higher than normal (Appendix C, Table 3). Phase III samples were analyzed by Analytical Technologies, Inc. Because of the importance of these tests, turnaround time was not as important as detection limits. Therefore, lower detection limits were attained in most cases.

3.3 COLLECTION OF REPRESENTATIVE SAMPLES

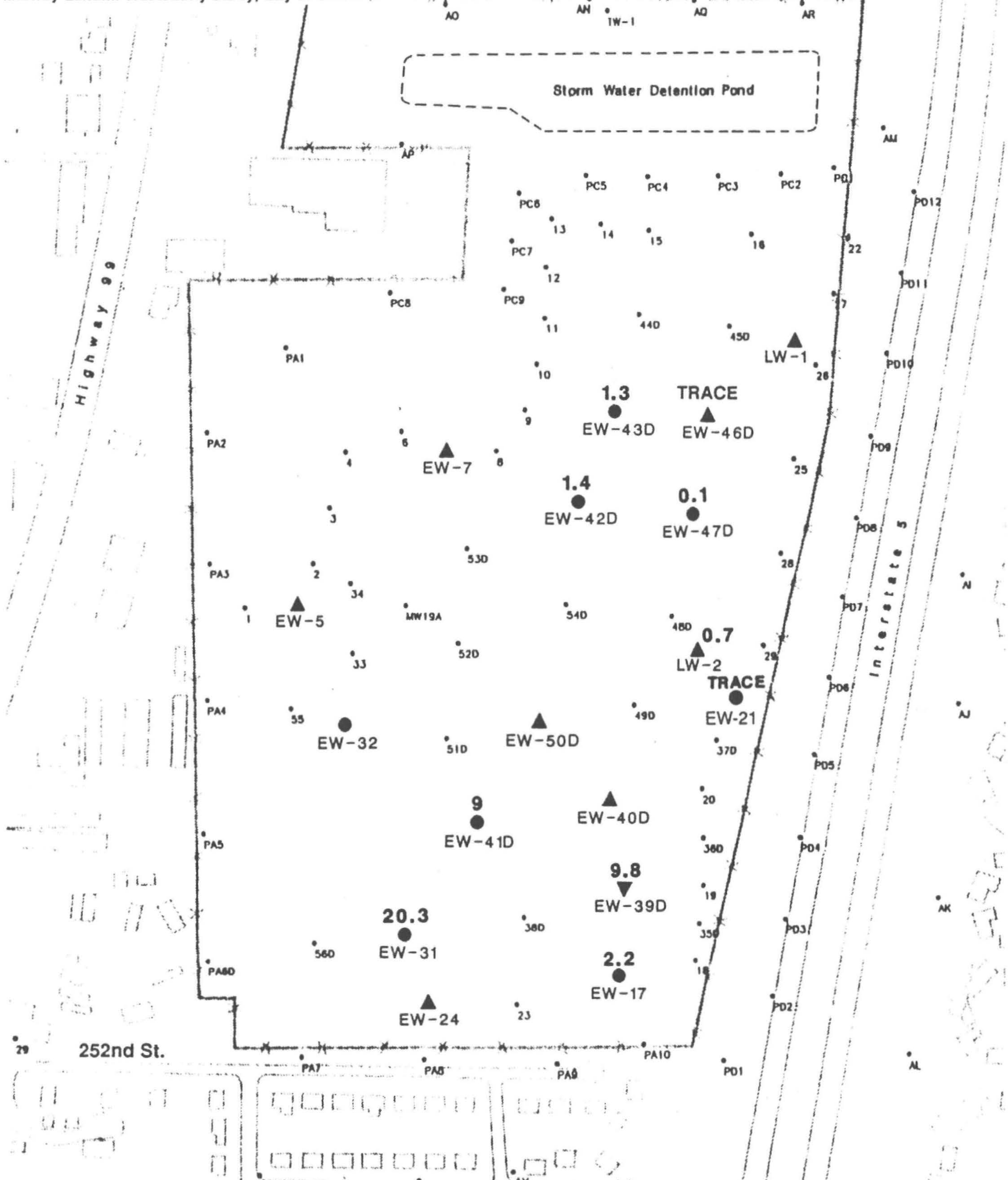
The location of the eight Midway Landfill wells from which the leachate samples were taken is shown in Figure 3.1. These wells were considered to be representative of the APL present at the site for the following reasons:

- They are single phase wells (no NAPL) but are close enough to wells containing NAPL to be possibly influenced by the presence of oil.

- They contain at least 10 feet of water and, presumably, represent thicker zones of saturation; and therefore, larger volumes of extractable leachate.

- They have specific conductances and pHs that are near or above average for the Midway leachate.

- They reasonably span the area of the landfill.



Parametrix, Inc.

Fenced Site Boundary

23 Gas Probe, Gas Extraction Well, or Groundwater Monitoring Well Number and Location

1.3 Maximum Oil Thickness Observed Between November 1988 and March 1990

Well Sampled in November 1989 for Treatability Study

Well Sampled in January 1990 to Obtain Oil for Treatability Study

N

SCALE IN FEET

0 150 300

Figure 3.1
Sampling Locations

Conductivity, pH, and temperature were measured at the well head for each well. Before collecting samples, the wells were purged with two casing volumes and/or until pH, conductivity, and temperature readings stabilized to within 10-15%. A total of 160 L of APL (20 L from each well) was collected from the eight landfill wells. The bulk samples were stored in amber glass containers at 4° C at the Enviros, AGI, and ATI laboratories. Similar containers and conditions were used to store composite leachate samples. The containers were certified pre-cleaned by the manufacturer.

To prevent the loss of organic and inorganic contaminants present in the leachate, care was taken to minimize head space in the containers. However, air was introduced into the system when the containers were rotated or shaken to assure uniformity of the contents before composite samples were prepared or test samples withdrawn. Despite the potential for loss of some contaminants during the mixing process, this method was used because it could likely simulate actual processing conditions.

Redox potentials were not measured at the well head because the landfill is known to be operating under methogenic conditions and to contain measurable concentrations of ammonia and sulfide. The sulfide would react with the redox probe and poison its surface, ruining the measurements. The leachate should be considered to be strongly anaerobic. Total suspended solids (TSS) and turbidity were not measured in the APL because these parameters increase with sample handling, especially with the introduction of oxygen into the system.

Consistent with the treatability study workplan, fresh composite leachate samples were prepared as follows:

- Thirty-two liters of sample were prepared at a time, 4 L from each well, to prevent head space in the containers.
- The containers holding leachate from each well were shaken or rotated to ensure uniformity of the contents.
- Equal volumes of approximately 500 ml were drawn from each of the eight leachate containers.
- The sample volumes were combined in a 4-liter amber glass container.
- The containers were shaken or rotated to mix the contents.
- The containers were shaken or rotated again before withdrawing each test sample.

3.4 QUALITATIVE PHASE

The qualitative phase of the study used composite APL from the landfill in flocculation/-sedimentation and froth flotation experiments. No samples were taken during this phase of the study. Instead, the goal of this phase was to visually assess the APL behavior under processing conditions. The processes evaluated were those with the best potential for providing suitable pretreatment of the APL.

The pH levels of the APL and air flowrates were adjusted and different foaming and flocculating agents were evaluated. From these qualitative experiments, froth flotation at an acidic pH was retained for further evaluation in Phase I. Ferric chloride and alum were also selected as flocculating agents for further evaluation in Phase I. In addition, adjustment of the pH level did not appear to help flocculation. The Qualitative Phase of the treatability study suggested that the flocculating agent dose should be optimized first before testing the effects of different pH levels on flocculation.

3.5 PHASE I

Phase I of the treatability study consisted of three separate groups of experiments: (1) oil/water separation, (2) flocculation, and (3) froth flotation. Each group of experiments is discussed in further detail below.

3.5.1 Oil/Water Separation

Oil was removed from Well EW-39D at the Midway Landfill and mixed with composite APL to (1) simulate the mixing of the two phases that may occur as the leachate is extracted from the landfill, and (2) evaluate the phase separation that would be required for treatment of the APL and disposal of the oil. Well EW-39D was selected because it was previously determined to have the highest level of PCBs in the oil.

The goals of the oil/water separation experiment were to (1) determine if the PCB concentration in the APL would be higher or significantly different when oil is present in the landfill wells, and (2) determine if PCBs and oil and grease concentrations in the APL would meet Metro pretreatment requirements without additional processing.

The experiment involved adding 500 ml of oil to 3 L of composite APL and shaking the mixture for 5 minutes. The mixture was allowed to sit overnight. After 24 hours, the mixture was shaken again for 5 minutes and then poured into a separatory funnel. Both phases were separated and samples were submitted for analysis. The APL was analyzed for PCBs and oil and grease, while the oil was analyzed for PCBs only.

Based on the analytical results, the PCB content of the oil remained basically unchanged. Initial analysis of the oil indicated a PCB concentration of 900 ppm. After mixing with the composite APL, the final PCB concentration in the oil was 940 ppm. The difference between these two numbers is insignificant due to the error within the analytical method.

The PCB concentration in the composite APL increased from an initial average of approximately 6 ppb to a maximum of 217 ppb after mixing with the oil. These results indicate that PCBs can be transferred to the APL when oil is present. Because the expected solubility of PCBs in distilled water is approximately 30 ppb, the transfer of PCBs from the Midway oil to the APL must be assisted by the presence of solvents and/or emulsifying agents.

PCB concentrations in the APL would meet Metro pretreatment requirements based on Metro's acceptance of waste from a local waste processor. The waste processor has a discharge limit for water containing PCBs at a concentration of 0.5 ppm (500 ppb). The oil and grease content of the APL also meets Metro standards without further pretreatment.

Results from the oil/water separation experiment indicate that both phases can be easily separated, and the PCB and oil and grease levels in the APL would meet Metro standards without further processing. Other contaminants in the separated Midway APL were not analyzed for. Therefore, a comparison of their concentrations to the Metro standards was not possible.

3.5.2 Flocculation

The goal of the flocculation process was to create a solid floc that also settled quickly and removed PCBs and metals. The flocculation experiments were broken down into four stages. The first stage involved testing the effect of different flocculants and doses. The second stage tested the effect of various pH levels. The third stage tested the effect of polymers. Finally, the fourth stage looked at settling rates of the floc. The optimum results or conditions from each stage of tests were used in each successive stage.

3.5.2.1 Dose Effects

Five different doses of alum and ferric chloride were added to composite APL and allowed to sit overnight. The optimum dose of ferric chloride proved to be the smallest dose. In order to get a better idea of the optimum dose of ferric chloride, four additional doses were tested. This second batch of doses were slightly greater or less than the optimum dose of ferric chloride from the first batch. Several doses in each group (alum and ferric chloride) produced a good quality floc and supernatant. The minimum dose that produced a good floc was carried into the pH tests. The optimum dose of ferric chloride produced a more compact floc than the optimum dose of alum. However, it was decided to carry the optimum dose of alum into the next tests in order to be certain that ferric chloride was the better flocculent.

3.5.2.2 pH Effects

The optimum doses of the two flocculating agents were each tested at five different pH levels. The pH of the composite APL was first adjusted and then the flocculent was added. The ferric chloride mixtures appeared to clear (flocs separated from solution) faster than the alum mixtures. In addition, pH did not significantly affect the flocculent performance. Therefore, ferric chloride was chosen as the flocculating agent for further testing. The dose of ferric chloride was increased from 0.05 g/100 ml APL to 0.1 g/100 ml APL for the remaining testing stages. The larger dose cleared faster and also produced a clearer solution than the smaller dose. The pH 4.5 solution was the clearest. The pH 6 and 7 solutions were the next best. Because the difference was small and the preference is for as small a pH adjustment as possible, pH 4.5 was dropped from further consideration.

3.5.2.3 Polymer Effects

Four polymers from the Nalco Corporation and four from the Betz Industrial company were tested during this stage of experiments. The polymers were recommended by the manufacturers based on their review of the APL characteristics. These were liquid polymers that are commonly used in drinking water treatment. The polymers were added after the ferric chloride. The addition of the polymers helped the solutions clear faster (faster forming floc). Two of the Betz polymers worked better than the rest. The performance of these two polymers was close, but only one was chosen for further testing. The Betz polymer was then tested at two pH levels, 5 and 7. The pH 7 floc floated to the surface. The pH 5 floc sank to the bottom. The pH 7 mixture cleared faster and had a more compact floc than the mixture at pH 5.

3.5.2.4 Clearing/Settling Rates

The final stage of the Phase I flocculation experiments involved comparing the clearing or settling rates of large quantities (1 L) of the untreated composite APL and treated APL at three different pH levels, 5, 7 and 9. However, it is not sufficient to look at only clearing rates and clarity of the solution; samples must also be taken and analyzed for a more precise evaluation of the different processes. Samples were taken of the supernatant from the three treated APL mixtures. There was no observable clearing of the untreated APL. The pH 5 and 9 flocs sank to the bottom, while the pH 7 floc floated to the surface. The pH 9 mixture performed worse than the other treated APL mixtures; its clearing rate was the slowest and the supernatant was the darkest.

Samples were taken of the supernatant of all three APL mixtures and analyzed for benzene, ethylbenzene, toluene, and xylenes (BETX), chlorinated organics, and selected metals (iron, lead, and manganese). According to the analytical results (see Appendix C, Table 3), flocculation/sedimentation improved the APL quality such that detectable compound levels and detection limits for non-detects were significantly lowered. In addition, there was no significant correlation between pH and the removal efficiency of metals from the aqueous solution. Lead and iron concentrations were reduced in all cases.

No chlorinated compounds were detected in the solution before or after flocculation. BETX compounds were detected in the leachate from some of the Midway wells (see Table 1.1). There were no BETX compounds detected in the solution after flocculation at pH 9. The concentration of BETX compounds was slightly lower at pH 7 than at pH 5. All detectable BETX concentrations were below the Metro pretreatment requirements.

Flocculation did improve the clarity of the solution at all pHs. Because there was no significant difference in the contaminant removal efficiency of the flocculation/sedimentation process at the tested pHs, it will be technically advantageous to operate the treatment process at pH 7 – the pH of the composite APL – after it is mixed with the ferric chloride.

3.5.3 Froth Flotation

The goal of the froth flotation process was to create a neutral foam that would remove oils, PCBs, and colloidal metal oxides and hydroxides. Aeration, necessary to generate the foam, would have the added benefit of removing a large percentage of volatile compounds and possibly surfactants from the solution. Analytical results (Appendix C, Table 5) indicated that aeration of the APL through froth flotation reduced the concentration of VOCs in the sample. However, because the main goal of froth flotation was to reduce PCB concentrations (which are now not considered a major processing concern because of their low detected concentrations in the APL) at Midway, froth flotation was not evaluated further during the treatability study.

3.5.4 Conclusion

Analytical results from the Phase I oil/water separation and flocculation/sedimentation experiments indicate that these technologies could treat the APL to meet or surpass Metro pretreatment standards. Therefore, Phase II of the treatability study was not necessary and was not performed. The results from the Phase I flocculation/-sedimentation experiments are summarized in Table 3.1.

Ferric chloride performed better than alum as the flocculating agent for the flocculation/sedimentation process, and the optimum dose of ferric chloride was identified. Through analytical testing, it was determined that the contaminant removal efficiency of the flocculation process did not vary significantly with pH. Therefore, it was decided that this portion of the process would operate without pH adjustment of the APL. Analytical results also indicated that the flocculation/sedimentation process was capable of reducing higher concentrations of PCBs if PCBs were encountered during the APL treatment process.

Table 3.1. Summary of the results of the Phase I flocculation/sedimentation experiments.

Experiment		Ranking[a]
Stage 1 - Dose Effects:		
Alum	0.1 g	5
	0.5 g	2
	1.0 g	1
	1.5 g	3
	2.0 g	4
Ferric Chloride	0.1 g	1
	0.5 g	2
	1.0 g	3
	1.5 g	4
	2.0 g	5
	0.01 g	4
	0.05 g	3
	0.15 g	2
	0.20 g	1
Stage 2 - pH Effects:		
Alum	pH 4.5	5
	pH 6	4
	pH 7	3
	pH 8	1
	pH 9.5	2
Ferric Chloride	pH 4.5	NSD
	pH 6	NSD
	pH 7	NSD
	pH 8	NSD
	pH 9.5	NSD
Stage 3 - Polymer Effects:		
Nalco polymers	672	2
	673	3
	674	5
	675	4
	no polymer	1
Betz polymers	1115L	1
	1125L	2
	1131L	4
Nalco polymer	672	3
Stage 4 - Clearing/Settling Rates:		
Untreated APL		4
Treated APL at pH 5		2
Treated APL at pH 7		1
Treated APL at pH 9		3

[a] A ranking of 1 = most effective, 5 = least effective.

NSD = No significant difference between the pHs.

3.6 PHASE III

Phase III of the treatability study was designed to test the processes that had provided the best results, and to verify those results with sampling and analysis experiments run in triplicate.

Phase III involved combining the two most promising APL treatment technologies, oil/water separation and flocculation/sedimentation. Oil from Well EW-39D was added to the APL in approximately a ratio of 1:25 and run through the process in triplicate. Samples were taken along each step of the process to evaluate the effluent quality and verify that Metro pretreatment standards had been attained or surpassed. The analytical results of the effluent from the flocculation/sedimentation step are summarized in Table 3.2. (For a complete listing of the analytical results, see Appendix D, Tables 4 and 5.)

Table 3.2. Summary of analytical results of the effluent from the Phase III oil/water separation and flocculation/sedimentation experiments.

	Total Contaminant Level[a]			
Contaminant	Comp. APL	After Oil/Water Separation	After Oil/Water Sep. and Floc./Sed.[b]	Decrease[c] (%)
VOCs (ppb)	940	1,074	783	27
PCBs (ppb)	20.6	510	5.9	99
PAHs (ppb)	243	3,780	86.8	98
Metals (ppm)	0.982	0.9018	0.6077	33
BOD (ppm)	93	365	81.4	78
COD (ppm)	6,830	1,500	1,129	25
Oil and Grease (ppm)	NA	100	8.3	92

[a] The totals do not include non-detects (ND) and estimated quantities (J).

[b] The totals in this column were calculated using the geometric means of detectable compounds from the three sample runs.

[c] Percent decrease calculated from "After Oil/Water Separation" to "After Oil/Water Sep. and Floc./Sed."

NA = Not analyzed.

Sludge from the flocculation process was initially dewatered using a sand column. However, because the sand was not sufficiently porous to allow the water to pass through in a reasonable amount of time, a centrifuge was used to dewater the remaining sludge samples. The sludge was analyzed for metals and semi-volatile compounds using the toxicity characteristic leaching procedure (TCLP), PCBs, TPH, and percent moisture. Based on the analytical results, the sludge would be classified as a solid waste. The sludge would be acceptable for disposal at a solid waste municipal landfill (Appendix D).

Analytical results from the first step in the Phase III treatment process – oil/water separation (Alternative 1) – indicated that PCBs and metals in the APL were reduced to levels that may be acceptable to Des Moines. However, the oil and grease content of the APL after this stage was near the Metro limit of 100 ppm. The amount of time the oil was in contact with the APL was only 24 hours. However, the ratio of oil to APL was considerably higher than was expected to occur in actual practice. This ratio of oil to APL also provided a more difficult test of the flocculation/sedimentation step.

The elevated concentration of PCBs and PAHs in the APL after oil/water separation was probably due to the presence of oil. These contaminants are being transferred to the APL from the oil, but at levels that are below their solubility in water. Data from the froth flotation experiment in Phase I indicated the level of volatile compounds in the APL can be reduced through aeration.

Oil/water separation by itself (Alternative 1) may be an insufficient treatment due to the variability of the leachate characteristics. If further treatment is necessary, flocculation/sedimentation (Alternative 3) will be added to the treatment process. Phase III of the treatability study demonstrated that this technology met the contaminant removal goals that would allow discharge to the Des Moines system.

Analytical results from the second step in the Phase III treatment process – flocculation/sedimentation – indicated that all parameter levels had decreased. Comparison of the effluent concentrations of certain compounds of concern before flocculation ("After Oil/Water Separation" column in Table 3.2) and after flocculation show the following average decreases: VOCs-27%, PCBs-99%, metals-33%, BOD-78%, COD-25%, and oil and grease-92%. Although the VOC levels exceeded the performance goals, they appear to be within Metro's pretreatment standards found in the Kent Highlands/Midway discharge permits and other discharge permits. All other parameters met the performance goals.

The results of the collection and analysis of a large number of samples at many locations over a period of six years have provided confidence in the leachate contaminant characterization (AGI 1990). Ecology assisted in selecting the last set of leachate sampling points and these samples confirmed the results from previous sampling rounds. If the leachate treatment is implemented, the leachate composition will be monitored. Adjustments will be made to the treatment process if monitoring results indicate changes in the contaminant levels sufficient to affect effluent quality. The process strings presented here can be changed or added to if adjustments are needed to respond to leachate composition changes.

4. CONCEPTUAL DESIGN OF THE ALTERNATIVES

This chapter provides a detailed description and conceptual design of the final remedial action alternatives for pretreatment of the Midway APL. These alternatives, selected from the screening process performed in Chapter 2 and the bench-scale treatability studies summarized in Chapter 3, are identified as:

<u>Alternative 1</u>: Oil/water separation; collection and onsite incineration of volatile gases; collection and transportation of NAPL to permitted incinerator; discharge of the APL to Des Moines.

<u>Alternative 3</u>: Oil/water separation in combination with flocculation/sedimentation; collection and onsite incineration of volatile gases and stripped volatile organics; collection and transportation of NAPL to permitted incinerator; discharge of the pretreated APL to Des Moines; dewatering of sludge and disposal at municipal landfill.

The conceptual designs provided here will then be used as the basis for performing detailed evaluations of the alternatives, and developing order-of-magnitude cost estimates with an accuracy of -30 to +50% (Chapter 5).

4.1 DETAILED DESCRIPTION OF THE REMEDIAL ACTION ALTERNATIVES

4.1.1 <u>Description Elements</u>

The description of each remedial alternative includes the following:

- The intent of the remedial alternative, such as pretreatment or final treatment of the leachate
- A description of the key technologies comprising each alternative
- A preliminary conceptual design of the major components, equipment, and facilities required
- Construction, operation, and maintenance considerations.

4.1.2 <u>Design Assumptions</u>

Several assumptions were made in order to conceptually design the remedial alternatives. These assumptions are based on the extractable volumes of oil and APL from the landfill, results of the treatability studies, and proposed automation of the process operations. These assumptions include:

- For the treatability study report, each alternative will be conceptually designed and costed from the point the APL reaches the pretreatment system to discharge to the pipeline to Des Moines. The design and costing of the systems necessary to bring the APL and NAPL to the pretreatment system and discharge the pretreated APL to Des Moines will be performed in the associated feasibility study report.

- The flowrate of APL from the landfill to the oil/water separator will be 40 gpm. This assumes that the present groundwater inflow continues and that 100% of the groundwater is captured in the leachate extraction system.

- Retention time in the oil/water separator will be 30 minutes.

- The total volume of extractable PCB-contaminated oil from the landfill is estimated to be 2,200 gallons (AGI 1990a). The worst-case scenario will be assumed, and the system designed so that all 2,200 gallons are removed in the first year. However, for years 2 through 10, it will be assumed an additional 220 gallons per year of oil will be extractable from the landfill. No oil will be extractable from the landfill for years 11 through 30. The inflow of oil to the oil/water separator only slightly reduces the feed stream volume to the subsequent pretreatment units. Assume the combined APL/NAPL feed remains at 40 gpm to units downstream of the oil/water separator.

- The APL and oil extraction process will be automated to operate 24 hours per day, 7 days per week. Extraction and pretreatment of the APL will be performed for 30 years.

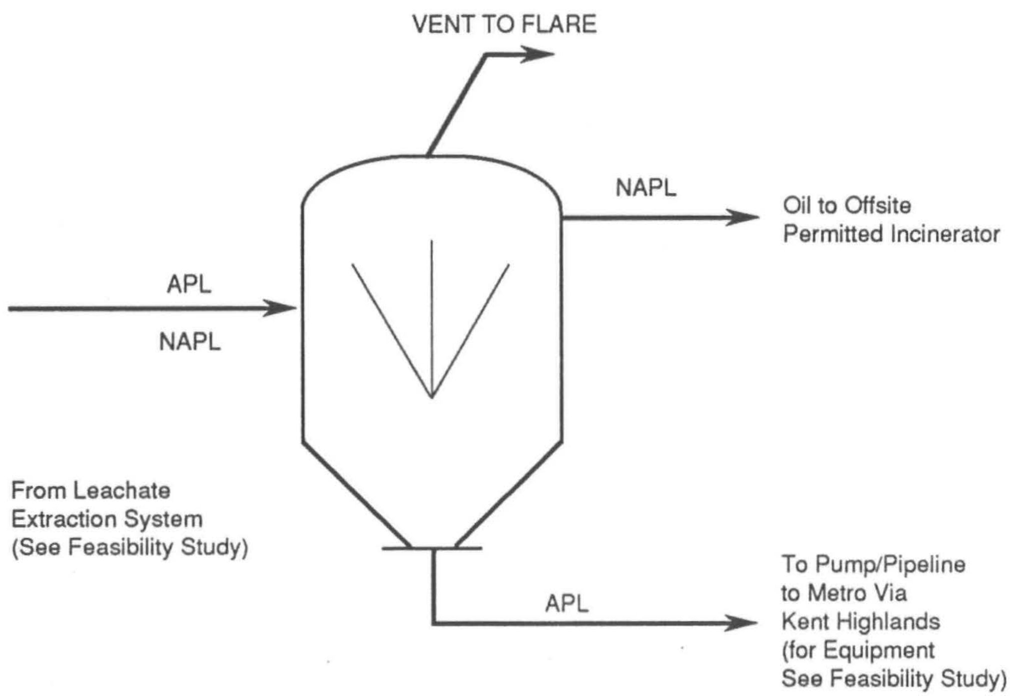
- The Alternative 1 oil/water separation system will be automated for 24-hour processing (Figure 4.1).

- Alternative 3 will consist of three pretreatment options that will be conceptually designed in this chapter. These process options include:

  - A process that will be manned 8 hours per day and operated 6 hours per day, 7 days per week.

  - A process that will be operated and manned 24 hours per day, 7 days per week.

  - A process that will be operated 24 hours per day, 7 days per week, and manned 8 hours per day, 7 days per week. The process will be automated to operate 16 hours per day, 7 days per week.



OIL/WATER SEPARATOR
WITH 200% CONTAINMENT
FLOW RATE: 40 gpm
UNIT SIZE: 2,000 gallons

APL Aqueous Phase Liquid
NAPL Nonaqueous Phase Liquid

Figure 4.1
Alternative 1
Liquid Process

- Oil taken from the separator and skimmed from the surface of the storage tanks will be drummed (using 55-gallon containers) and shipped to an offsite permitted PCB incineration facility. The cost of oil disposal is $825.00 per 55-gallon drum. This cost includes transportation to the incinerator and necessary laboratory testing. In addition, pickup of the oil drums at the landfill site will cost $150.00 per trip. The truck can hold 25-30 drums per trip. Assume a pickup will be made at least once every 90 days.

- One gram of ferric salt per liter of APL will be added in-line upstream of the pump that feeds the mixer. It is recommended a liquid ferric salt solution be used. The mixer will process the rates shown in Figure 4.2, including the recycle water from the filter press, for 6 hours per day for Alternative 3a and for 24 hours per day for Alternatives 3b and 3c.

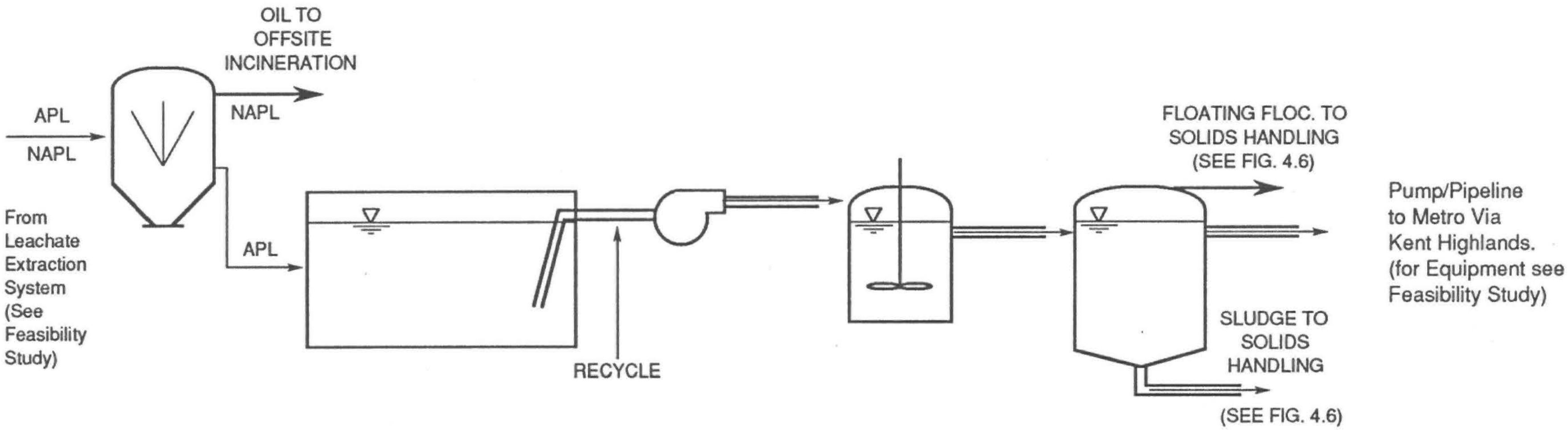
- Five ml of a 0.1-percent polymer solution per liter of APL will be added in-line upstream of the feed that enters the clarifier. Including the recycle rate from the filter press, the feed to the clarifier will be as shown in Figure 4.2.

- The hydraulic retention time in the clarifier will be based on solids settling data obtained from Phase I of the treatability study (see Appendix C). Approximately 10% by volume of the material from the clarifier will be wet solids. Approximately 90% by volume will be aqueous liquid.

- Pretreated APL will be discharged to Des Moines without additional pretreatment to reduce the concentration of VOCs. If Des Moines determines that VOC pretreatment is necessary, this system will be conceptually designed and costed in the associated feasibility study.

- Wet solids from the clarifier can be dewatered to 30-40% solids by weight in the plate-and-frame filter press. Effluent from the solids and filter wash-water will be recycled to the process upstream of the pump feeding the mixer. The filter press will be manually operated. Suitable air in the breathing zone will be maintained for the workers using fan-driven ventilation.

- Dewatered solids from the filter press will be stored in a covered container for bulk disposal. Based on analytical data from the Phase III experiments, the solids will be disposed of at a local municipal landfill at a cost of approximately $80.00 per ton, excluding transportation.



NAMES		Oil/Water Separator	Storage Tanks	Pump	Flash Mixer	Clarifier
FLOW RATE	**Alt. 3a**	40 gpm		176 gpm		176 gpm; 540 gpdp ft^2
	Alt. 3b	40 gpm	Not necessary	44 gpm		44 gpm; 540 gpdp ft^2
	Alt. 3c	40 gpm	Not necessary	44 gpm		44 gpm; 540 gpdp ft^2
UNIT SIZES	**Alt. 3a**	2,000 gallons	2 - 22,000 gallons	1 HP	2,400 gallons	380 ft^2; 22 ft. diameter
	Alt. 3b	2,000 gallons	Not necessary	1/2 HP	650 gallons	95 ft^2; 11 ft. diameter
	Alt. 3c	2,000 gallons	Not necessary	1/2 HP	650 gallons	95 ft^2; 11 ft. diameter

Parametrix, Inc.

gpdp ft^2	Gallons/Day/Square Feet
APL	Aqueous Phase Liquid
NAPL	Nonaqueous Phase Liquid
gpm	Gallons Per Minute
HP	Horsepower
ft^2	Square Feet

Figure 4.2
Flow Rates and Unit Sizes
Alternatives 3a, 3b, 3c

- Unless otherwise specified, all pretreatment units will have a negative pressure vapor collection system. To prevent introducing excess oxygen into the existing landfill gas collection system and potentially creating an explosive environment, the volatile gases and stripped volatile organics from the pretreatment units will be fed to the existing landfill flares as part of the inlet air stream. The flares have been designed to operate within a range of temperatures and retention times to provide destruction of hydrocarbon compounds. Continued air monitoring around the landfill will verify these contaminants have been destroyed. The vapor from each unit will be discharged to the air intake of each of the existing flares at Midway at a rate of 5 cubic feet per minute (cfm).

- The cost estimates developed for the treatment facilities are for industrial-type facilities, rather than municipal-type facilities. This means, for instance, that the buildings will be metal buildings rather than permanent concrete structures. The treatment facilities are not developed with redundant units, however, the single unit operations are reasonably reliable because appropriate spare parts are provided to minimize downtime due to any equipment failure.

4.1.3 Selected Alternatives

4.1.3.1 Alternative 1

The intent of this alternative is to pretreat the Midway APL to satisfy the Metro discharge standards. This alternative involves separating the APL from the NAPL and discharging the APL to Des Moines for additional treatment. The NAPL would be detoxified at an offsite permitted incineration facility (see Figure 4.1).

APL from the Midway Landfill will be pumped to an oil/water separator at the rate of 40 gpm, 24 hours per day, 7 days per week. The capacity of the separator will be 2,000 gallons. The separator will have a containment structure for 200% of the total volume, and will be operated under negative pressure to prevent volatile gases from being discharged directly to the environment.

The negative pressure vapor collection system for the oil/water separator will consist of small diameter polyvinylchloride (pvc) piping connected to a small motor blower discharging to the air inlet of each flare. The piping at each air feed inlet to the flare will be symmetrical to allow even airflow to both sides of the flare. The vent system will be valved at the flare facility to allow flow to any or all of the flares as required. Prior to system branching, a flame arrestor will be installed to prevent backflash from the flares to the leachate pretreatment unit. Condensate from the vapor system will be collected and disposed of through the existing landfill gas collection system/condensate removal system. The capacity of the vapor collection system for Alternative 1 will be 5 cfm.

Floating PCB-contaminated oil will be withdrawn from the separator and packaged in Department of Transportation Specification 5 containers without a removable head. The containers will be placed in a storage area within a containment structure capable of holding 100% of the total stored volume. At least once every 90 days, the oil will be removed from storage and transported offsite to a TSCA-permitted incineration facility.

APL from the separator will be pumped at a rate of 40 gpm to the pipeline located along the east side of SR-99 where it will be conveyed to the Des Moines sanitary sewer system for additional treatment.

Operation and maintenance activities would include regular collection and shipment of the oil, periodic cleaning of the oil/water separator, sampling and analysis of the effluent discharge, and limited general maintenance. Level controls would be installed in the separator to prevent overflows or excessive backpressure. The controls would be connected to the well-pumps to shut them off in response to high liquid levels or equipment failures.

4.1.3.2 Alternatives 3a, 3b, and 3c.

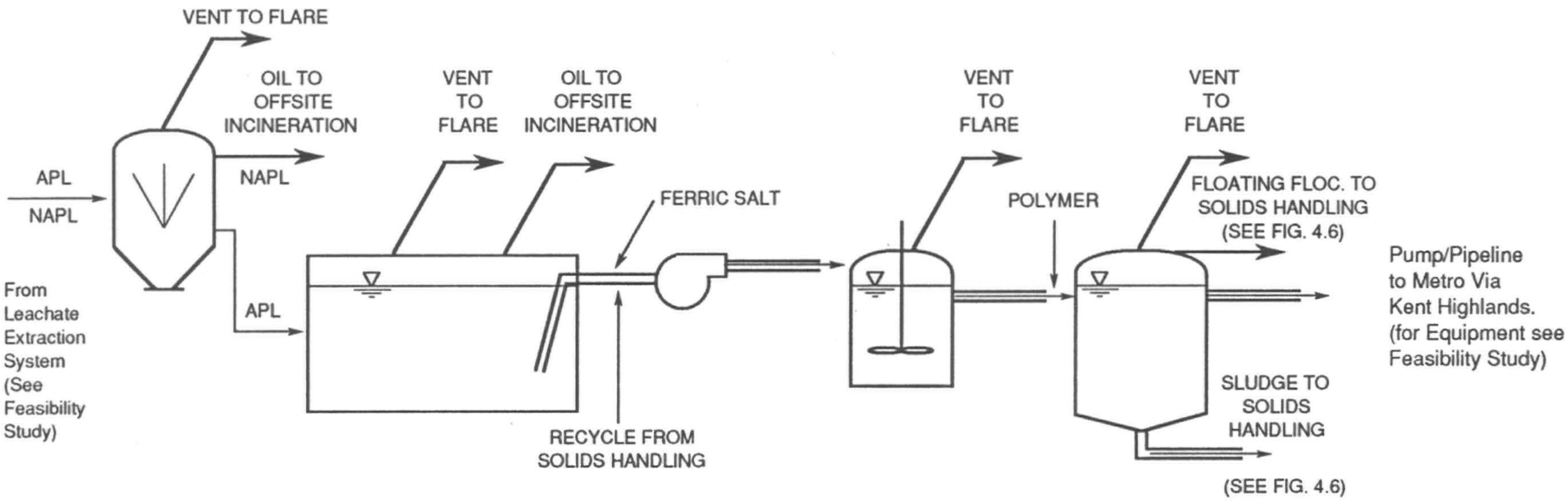
Alternatives 3a, 3b, and 3c consist of the same oil/water separation process described in Alternative 1. Alternatives 3a, 3b, and 3c provide additional pretreatment of the Midway APL in the form of flocculation/sedimentation (Figures 4.3, 4.4, and 4.5). As with Alternative 1, the intent of these alternatives is to provide pretreatment of the APL to satisfy Metro discharge standards before discharge to Des Moines sanitary sewer. Des Moines will provide additional treatment of the Midway effluent. Unless specified otherwise, each pretreatment unit comprising Alternatives 3a, 3b, and 3c will be enclosed and vented to the existing landfill flares at a rate of 5 cfm per unit as described in Alternative 1. The total venting capacity of the Alternative 3 processes will be 20 cfm.

Ferric chloride acts as both a flocculent and an oxidant and should be able to handle the anaerobic leachate. If the flocculation efficiency decreases during actual process operation due to the presence of too much ferrous iron, then a holding/aeration tank will be added to the process before the flash mixer. In Alternative 3a, this could be accomplished in the holding tank.

Alternative 3a

Alternative 3a differs from Alternatives 3b and 3c because its treatment process only operates 6 hours per day (see Figure 4.2). Because the leachate extraction system is assumed to operate 24 hours per day, storage is required to contain 16 hours of APL, and the process rate is four times the leachate extraction rate.

APL from the oil/water separator will flow to two 22,000-gallon covered rectangular storage tanks at a rate of 40 gpm. The tanks will be situated within a containment structure capable of holding 100% of the total tank volume.

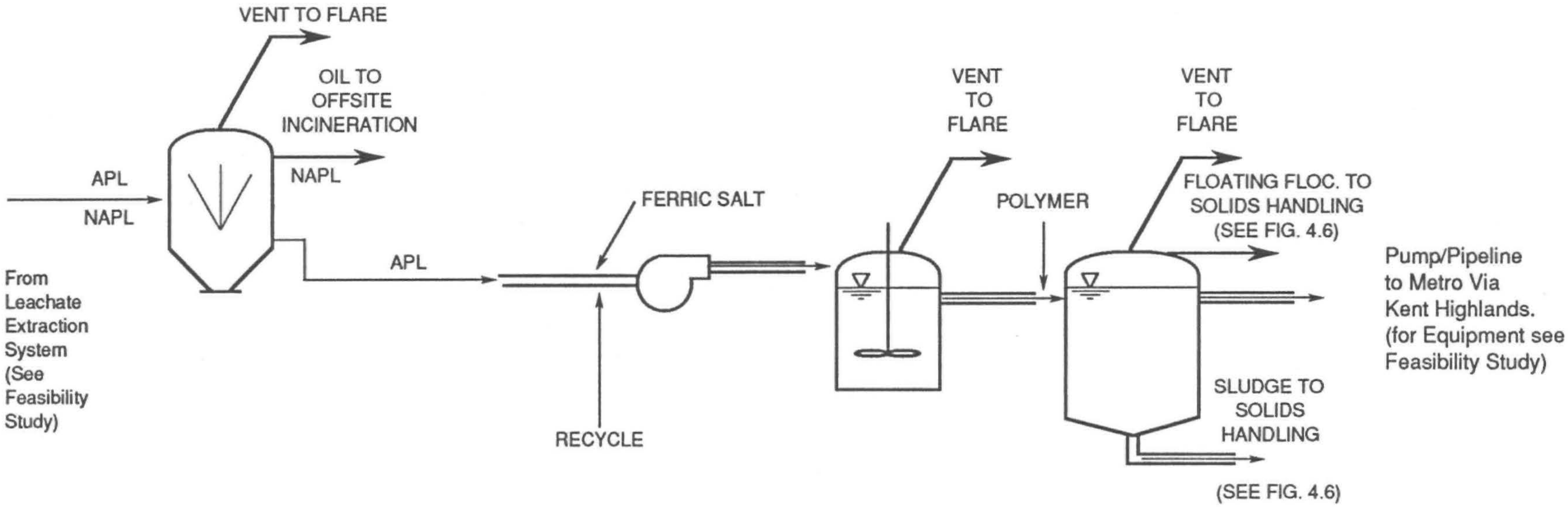


NAMES	Oil/Water Separator with 200% Containment	Storage Tanks with Sealed Covers and Oil Skimmers. Containment for 100% of Tank Volume	Pump Inlet Pipeline	Pump	Flash Mixer	Clarifier with Sludge and Floating Flocculant Drawoffs	
FLOW RATE	40 gpm		160 gpm +16 gpm recycle	176 gpm		176 gpm 540 gallons/day/ft^2 overflow rate	160 gpm
UNIT SIZES	2,000 gallons	2 - 22,000 gallons		1 HP	2,400 gallons 0.75 HP mixer	380 ft^2 surface area 22 ft diameter	
CONTROLS		Float switch stops pumps when tanks are full. High level alarm		Float switch in mixer tank	Manual with level alarms	Manual with level alarms	

Parametrix, Inc.

APL Aqueous Phase Liquid
NAPL Nonaqueous Phase Liquid
gpm Gallon Per Minute
HP Horsepower
ft^2 Square Feet

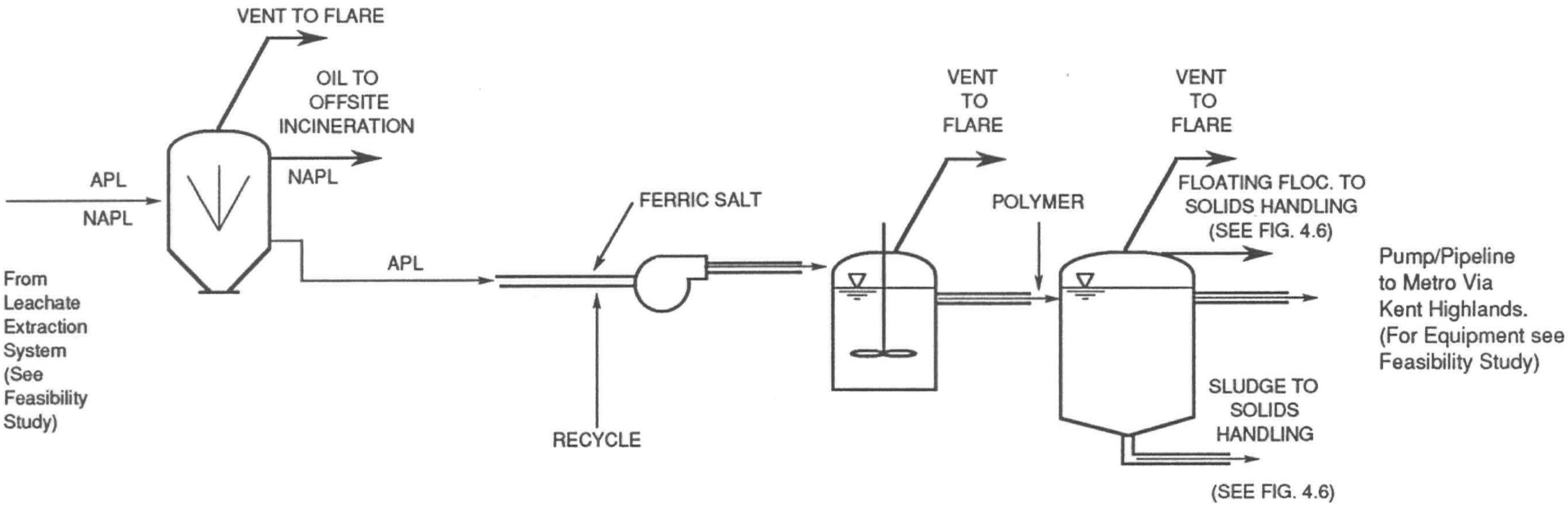
Figure 4.3
Alternative 3a
Liquid Process



NAMES	Oil/Water Separator with 200% Containment	Pump Inlet Pipeline	Pump	Flash Mixer	Clarifier with Sludge and Floating Flocculant Drawoffs	
FLOW RATE	40 gpm	40 gpm +4 gpm Recycle	44 gpm		44 gpm 540 gallons/day/ft^2 overflow rate	40 gpm
UNIT SIZES	2,000 gallons		1/2 HP	650 gallons 0.75 HP mixer	95 ft^2 surface area 11 ft diameter	
CONTROLS			Float switch in mixer tank	Manual with level alarms	Manual with level alarms	

APL	Aqueous Phase Liquid
NAPL	Nonaqueous Phase Liquid
gpm	Gallon Per Minute
HP	Horsepower
ft^2	Square Feet

Figure 4.4
Alternative 3b
Liquid Process



NAMES	Oil/Water Separator with 200% Containment	Pump Inlet Pipeline	Pump	Flash Mixer	Clarifier with Sludge and Floating Flocculant Drawoffs	
FLOW RATE	40 gpm	40 gpm +4 gpm recycle	44 gpm		44 gpm 540 gallons/day/ft^2 overflow rate	40 gpm
UNIT SIZES	2,000 gallons		1/2 HP	650 gallons 0.75 HP Mixer	95 ft^2 surface area 11 ft diameter	
CONTROLS			Float switch in mixer tank	Manual with level alarms	Manual with level alarms	

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APL Aqueous Phase Liquid
NAPL Nonaqueous Phase Liquid
gpm Gallon Per Minute
HP Horsepower
ft^2 Square Feet

Figure 4.5
Alternative 3c
Liquid Process

Residual oil captured in the tanks will be skimmed from the surface and added to the oil from the separator. This oil will be stored and shipped to an offsite TSCA-permitted incineration facility.

Ferric salt will be added in-line between the storage tanks and the mixer at the rate of 1 gram per liter of APL. The flowrate of APL to the mixer will be 176 gpm, including a recycle rate of 16 gpm from the filter press. The mixing tank will have a capacity of 2,500 gallons and be mixed with a 0.75 horsepower turbine mixer. The mixer will have a retention time of approximately 5 minutes.

A 0.1-percent polymer solution will be added in-line between the mixer and the clarifier at a rate of 5 ml per liter of APL. The flow rate to the clarifier will be 176 gpm. The clarifier will have a surface area of 380 square feet and an overflow rate of 540 gallons per day per square foot. Effluent from the clarifier will be pumped at a rate of 160 gpm to the pipeline located along the east side of SR-99 where it will be conveyed to the Des Moines sanitary sewer system for additional treatment.

Wet solids from the clarifier will be transferred via slurry pump to a 5,000-gallon holding tank at a rate of 16 gpm. Two 2-horsepower mixers will prevent the solids from coalescing (Figure 4.6).

Wet solids from the holding tank will be pumped at a rate of 16 gpm to a plate-and-frame filter press. Effluent from the press and filter wash-water will be recycled back to the process upstream of the pump feeding the mixer at a rate of approximately 16 gpm. Dewatered sludge will be stored in a covered hopper for bulk transport to a local municipal landfill.

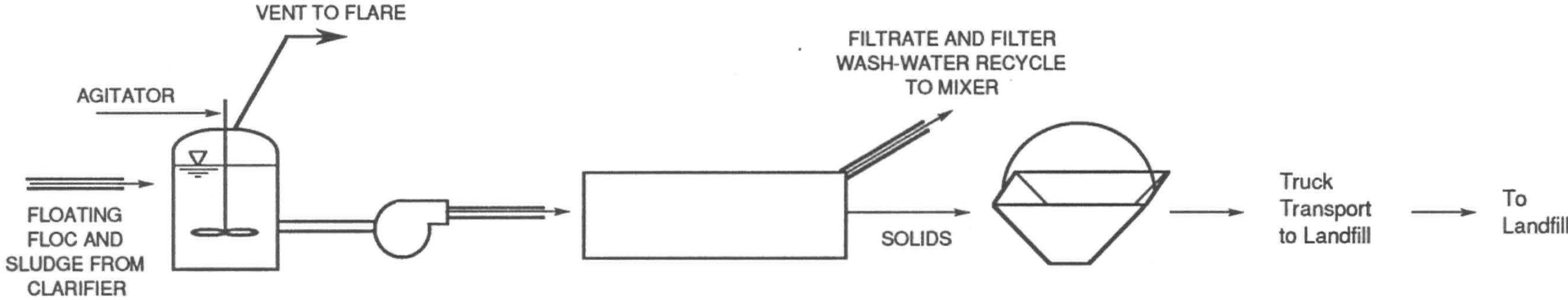
A negative pressure vapor collection system is not planned for the filter press. Suitable air in the breathing zone will be maintained for the workers using fan-driven ventilation.

A metal building would house certain process components, including the chemical preparation systems, process controls, and electrical systems. Process controls would be installed throughout the system to shut the operation down in response to high water levels or equipment failures. The most significant controls would regulate the well-pumps and pumps from the APL holding tanks.

Operation and maintenance activities for this alternative would be similar to those of Alternative 1. However, a less rigorous sampling and analysis program would be expected because of the additional pretreatment provided.

Alternatives 3b and 3c

Alternatives 3b and 3c both have all their liquid process units operating 24 hours per day. Therefore, Alternatives 3b and 3c do not require storage tanks for the APL upstream of their liquid process units. Their solids handling facilities operate only on-shift or 6 hours per day.



NAMES		Solids Holding Tank with Containment	Sludge Pump	Plate and Frame Filter Press	Bulk Storage Hopper with Cover
FLOW RATE	16 gpm[1] 4 gpm[2]		16 gpm	16 gpm recycle 0.12 gpm dewatered solids	
UNIT SIZES		5,000 gallons 2 HP mixer	1 HP	25 plates each 2' x 2' 7 ft^3/cycle 2 cycles/day	Truck load +50%
CONTROLS		Manual with level alarms	Manual	Manual	Manual

Parametrix, Inc.

Notes: 1. Sludge and floating floc from Alternative 3a.
2. Sludge and floating floc from Alternatives 3b and 3c.

HP Horsepower
gpm Gallons per Minute
ft^3 Cubic Feet

Figure 4.6
Solids Handling for Alternatives 3a, 3b, 3c

These two alternatives are alike except that Alternative 3b has manned operation 24 hours per day, while Alternative 3c is manned 8 hours per day and operates automatically 16 hours per day. The following is a description of the process units for both Alternatives 3b and 3c.

APL from the oil/water separator will be combined with recycle from the filter press and pumped directly to the mixer at an average rate of 44 gpm. The recycle rate is 4 gpm. The pump is rated at 0.5 horsepower. Oil from the separator will be stored and shipped to an offsite TSCA-permitted incineration facility.

Ferric salt will be added in-line between the separator and the pump feeding the mixer at the rate of 1 gram per liter of APL. The mixing tank will have a capacity of 650 gallons and be mixed with a 0.75-horsepower turbine mixer. The mixer will have a retention time of approximately 5 minutes.

A 0.1-percent polymer solution will be added in-line between the mixer and the clarifier at a rate of 5 ml per liter of APL. The flow rate to the clarifier will be 44 gpm. The clarifier will have a surface area of 95 square feet and an overflow rate of 540 gallons per day per square foot. Effluent from the clarifier will be pumped at a rate of 40 gpm to the pipeline located along the east side of SR-99 where it will be conveyed to the Des Moines sanitary sewer system for additional treatment.

Wet solids from the clarifier will be transferred via slurry pump to a 5,000-gallon holding tank at a rate of 4 gpm. Two 2-horsepower mixers will prevent the solids from coalescing (see Figure 4.6).

Wet solids from the holding tank will be pumped at a rate of 16 gpm to a plate-and-frame filter press. Effluent from the press and filter wash-water will be recycled back to the process upstream of the pump feeding the mixer at a rate of approximately 16 gpm based on a 6-hour operational period. Dewatered sludge will be stored in a covered hopper for bulk transport to a local municipal landfill.

A negative pressure vapor collection system is not planned for the filter press. Suitable air in the breathing zone will be maintained for the workers using fan-driven ventilation.

A metal building would house certain process components, including the chemical preparation systems, process controls, and electrical systems. Process controls would be installed throughout the system to shut the operation down in response to high water levels or equipment failures. The most significant controls would regulate the well-pumps and pumps from the APL holding tanks.

Operation and maintenance activities for this alternative would be similar to those of Alternative 1. However, a less rigorous sampling and analysis program would be expected because of the additional pretreatment provided.

5. DETAILED EVALUATION OF REMEDIAL ALTERNATIVES

This section provides a detailed evaluation of the remedial alternatives screened in Chapter 2 and the treatability studies summarized in Chapter 3. A detailed description of these alternatives focusing on key features such as technologies that comprise each alternative and short- and long-term construction, operation, and maintenance requirements was provided in Chapter 4. The detailed analyses conducted here will be used for comparing the alternatives and selecting the most appropriate remedial action for pretreatment of the Midway APL (Chapter 6).

The intent of this section is not to direct the reader toward a preferred alternative. Instead, it is intended to be a method of analyzing and presenting information needed to make an informed decision.

5.1 EVALUATION PROCESS

5.1.1 Evaluation Criteria

According to the EPA guidance for conducting feasibility studies under CERCLA (EPA 1988), the criteria for evaluating the alternatives should include:

- Overall protection of human health and the environment
- Compliance with the ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, and volume
- Short-term effectiveness
- Implementability
- Cost.

Specific elements that should be addressed within each of the performance criteria are presented in Table 5.1. These elements are discussed in detail in the following pages for each of the alternatives considered for pretreatment of the APL. A tabular summary of these evaluations is also provided.

The assessment of each alternative against the first criterion describes how the remedial action achieves and maintains protection of human health and the environment, and how risks posed through the previously identified exposure pathways are eliminated, reduced, or controlled through implementation of the alternative. The evaluation of each alternative and its compliance with the ARARs is used to determine whether each alternative will meet the performance goals specified in Chapter 2.

Table 5.1. Criteria for detailed evaluation of the remedial alternatives.

1. Overall protection of human health and the environment.

2. Compliance with the ARARs.

3. Long-term effectiveness and permanence
   - Magnitude of residual risk
   - Adequacy and reliability of controls.

4. Reduction of toxicity, mobility, or volume through treatment
   - Treatment processes used and materials treated
   - Amount of hazardous materials destroyed or treated
   - Degree of expected reductions in toxicity, mobility, and volume
   - Degree to which the treatment is irreversible
   - Type and quantity of residual contamination remaining after treatment
   - Quantity and regulatory classification of sludge generated.

5. Short-term effectiveness
   - Protection of community during remedial actions
   - Protection of workers during remedial actions
   - Environmental impacts
   - Time until remedial action objectives are achieved.

6. Implementability
   - Ability to construct and operate the technology
   - Reliability of the technology
   - Ease of undertaking additional remedial actions, if necessary
   - Ability to monitor effectiveness of remedy
   - Ability to obtain approvals from other agencies
   - Coordination with other agencies
   - Availability of offsite treatment, storage, and disposal services and capacity
   - Availability of necessary equipment and specialists
   - Availability of prospective technologies.

7. Cost
   - Capital costs
   - Operating and maintenance costs
   - Present worth cost.

Evaluating the long-term effectiveness and permanence of the alternative addresses the results of the remedial action in terms of the risk remaining at the site after the remedial objectives have been met. The primary focus of this evaluation is to discuss the extent and effectiveness of the controls that may be required to manage the risk posed by residual or untreated wastes remaining at the site, or in the event technical components of the alternative need replacement.

The fourth evaluation criterion discusses the ability of each alternative to reduce the toxicity, mobility, and volume of the contamination. Preferred remedial actions will provide destruction of the toxic contaminants, reduction in the total mass of the toxic contaminants, and irreversible reduction in the mobility or total volume of the contaminated media.

The short-term effectiveness of each alternative evaluates the protection provided to the community and the workers during the remedial efforts. Environmental impacts related to the construction and implementation of the alternative are also discussed, as well as a time estimate for achieving the remedial response objectives.

The implementability criterion addresses the technical and administrative feasibility of implementing the alternative. It also addresses monitoring considerations to track the effectiveness of the remedy and the availability of various services and materials associated with the remedial action.

The cost of each alternative includes direct and indirect capital costs, as well as the operating and maintenance (O&M) costs over the anticipated 30-year treatment period. These costs are presented in present worth values. The costs are discussed separately in Section 5.4.

5.1.2 Performance Rating

The results of the detailed evaluation of each alternative were rated using the classification of *high*, *moderate*, or *low*. A summary of the evaluations and subjective ratings are provided in Table 5.2 to indicate the strengths and weaknesses of the alternatives relative to each other. Because "cost" is a relative term whose rating could vary widely from estimator to estimator, the cost of each alternative was not rated. For comparison purposes, the costs are summarized in Table 5.3 at the end of this chapter.

The following definitions have been given to the subjective rating scale used in this chapter:

- A *high* rating indicates the alternative satisfies the intent of the criteria.
- A *moderate* rating indicates the alternative partially satisfies the intent of the criteria.
- A *low* rating indicates the alternative does not satisfy the intent of the evaluation criteria.

Table 5.2 Summary of the detailed evaluations.

Criterion:	Alternatives Alt. 1: Oil/Water; Incinerate Gases Gases and NAPL; APL to Des Moines	 Alt. 3a, 3b, and 3c: Oil/Water; Floc/Sedimentation; Incinerate Gases and NAPL; APL to Des Moines; Sludge to Landfill
Overall Protection Human Health and Environment	Reduces or eliminates leachate available for offsite transport. Incinerate gases and NAPL. Minimal exposure to workers. No additional exposure to Des Moines.	Reduces or eliminates leachate available for offsite transport. Incinerates volatiles gases and NAPL. Minimal exposure to workers. No additional exposure to Des Moines.
Rating	High.	High.
Compliance with ARARs	Attains pretreatment standards. Incinerate gases and NAPL.	Attains pretreatment standards. Incinerate volatiles gases and NAPL. Sludge acceptable to municipal landfill.
Rating	High.	High.
Long-Term Effect and Permanence	Would treat mobilized contaminants. Routine maintenance to remain operable and effective. Adaptable to maintain compliance. Gases and NAPL detoxified.	Would treat mobilized contaminants. Routine maintenance to remain operable and effective. Adaptable to maintain compliance. Volatile gases and NAPL detoxified. No changes to sludge processing to attain potential future disposal requirements. Contaminants in sludge not mobile.
Rating	High.	High.
Reduction of Toxicity, Mobility, and Volume	Detoxifies gases and NAPL. Reduces toxicity of APL. Reduces or eliminates total leachate volume. Contaminants in sludge contained in permitted municipal landfill. Reduces groundwater contamination.	Detoxifies volatile gases and NAPL. Reduces toxicity of APL. Reduces or eliminates total leachate volume. Contaminants in sludge contained in permitted municipal landfill. Reduces groundwater contamination.
Rating	High.	High.
Short-Term Effect	Immediate effectiveness on start-up. No danger to public. Controlled for minimal exposure to workers. Incinerates gases and NAPL. Minimal construction impacts.	Immediate effectiveness on start-up. No danger to public. Controlled for minimal exposure to workers. Incinerates volatile gases and NAPL. Minimal construction impacts.
Rating	High.	High.
Implementability	Common techniques and materials. Reliable and readily available. Land available. Routine monitoring. No special permits required.	Common techniques and materials. Reliable and readily available. Land available. Routine monitoring. No special permits required.
Rating	High.	High.
Overall Rating	High.	High.

5.2 EVALUATION OF ALTERNATIVES

5.2.1 Alternative 1

This alternative involves separation of the APL from the NAPL with further treatment of the APL provided by the Des Moines sewer system. NAPL would be disposed of at an offsite TSCA-permitted incineration facility. Volatile gases from the separation unit would be collected and incinerated at the onsite landfill flares.

This alternative would be automated to operate 24 hours per day, 7 days per week. Operation and maintenance activities would include regular collection and shipment of the oil, periodic cleaning of the oil/water separator, sampling and analysis of the effluent discharge, and limited general maintenance. Level controls would be installed in the separator to prevent overflows or excessive backpressure. The controls would be connected to the well-pumps to shut them off because of high water levels.

5.2.1.1 Overall Protection of Human Health and the Environment

There are two primary exposure pathways to the groundwater contamination associated with the Midway Landfill: (1) ingestion of contaminated groundwater from a well, and (2) inhalation of contaminants through showering with contaminated groundwater. Because there are no water wells that extract contaminated groundwater from the area of the Midway Landfill, there are no current pathways of exposure to the contaminants from the site. Potential future exposure to the leachate contaminants through the groundwater system could exist if a water well was installed in an area of groundwater contamination.

Pretreatment of the leachate extracted from the Midway Landfill would reduce the concentration of contaminants related to potential future human exposure through the groundwater system.

Separation of the extracted APL from the NAPL would be conducted in an enclosed separation unit to minimize exposure to volatile gases. Volatile gases would be detoxified in the onsite permitted landfill flares. The NAPL would be permanently detoxified at an offsite TSCA-permitted facility. Facility workers would follow established health and safety requirements to minimize exposure during routine operation, maintenance, and monitoring activities. Because the discharge of APL to the Des Moines system would attain Metro's pretreatment standards, no additional risk to the Des Moines workers from the Midway APL would be expected. It would not be anticipated that discharge of pretreated APL to the Des Moines system would inhibit Des Moines from attaining its NPDES permit standards for discharge to the environment.

The rating for overall protection of human health and the environment is high.

5.2.1.2 Compliance with the ARARs

The ARAR for pretreatment of the Midway APL is based on the pretreatment requirements specified by the Metro sewer system. The separation of APL from the NAPL and discharge of the APL to the Des Moines system would satisfy Metro's pretreatment requirements. Attaining the Metro pretreatment limits would allow Des Moines to attain its NPDES permit specifications for discharge to the environment. The NAPL would be incinerated at a permitted facility. Volatile gases from the leachate separation process would be incinerated onsite through the permitted landfill flares.

The rating for compliance with the ARARs is high.

5.2.1.3 Long-term Effectiveness and Permanence

Implementation of Alternative 1 at the Midway Landfill would neither change the contaminants present in the refuse at the site, nor would it remove all the contaminants from the landfill refuse. However, those contaminants that were mobilized into the leachate from water moving through the refuse would be extracted and treated.

Routine upkeep and maintenance of the facility encompassing Alternative 1 would allow it to remain operable and effective. Modifications or additions to the pretreatment facility could be made in order to maintain compliance with potential future changes to the Metro pretreatment standards. No anticipated changes for the incineration of the NAPL would be expected.

The rating for long-term effectiveness and permanence is high.

5.2.1.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Pretreatment of the Midway leachate would consist of separation of the APL from the NAPL. The PCB-contaminated oil (NAPL) would be permanently detoxified through incineration at an offsite TSCA-permitted facility. Volatile gases from the pretreatment process would be detoxified through incineration at the onsite permitted flares. The toxicity of the APL would be reduced through the pretreatment process and additional treatment as performed by Des Moines.

The volume of leachate available for offsite transport through the groundwater system would be reduced or possibly eliminated. Therefore, the volume and mobility of contaminants that enter the groundwater system would be reduced.

The rating for reduction in the toxicity, mobility, and volume of the contaminants through treatment is high.

5.2.1.5 Short-term Effectiveness

Immediately upon start-up of the pretreatment alternative, the toxicity, mobility, and volume of the contaminants from the landfill would be reduced. This pretreatment would result in a reduction in the potential for future exposure of the contaminants to the community through the groundwater pathway.

The pretreatment facility would not create a danger to the public. It would be an aqueous process that is not explosive, flammable, or corrosive. Volatile gases released from the process would be collected and incinerated in the onsite permitted flares. The volatile gases would not create an additional pathway for human exposure to the contaminants. The NAPL would be permanently detoxified at a permitted incinerator. Measures including spill control and health and safety requirements would prevent or minimize the potential for exposure of workers to liquid or gaseous contaminants.

Environmental impacts associated with construction of the facility include noise, dust, and traffic. These impacts are expected to be minimal and could be mitigated by limiting the activity to the site.

The short-term effectiveness rating is high.

5.2.1.6 Implementability

The requirements for construction of this facility would involve common techniques and materials. Problems and delays in the construction would not be anticipated. The primary pretreatment unit for this alternative is an oil/water separator. This type of process unit is standard, reliable, and readily available for implementation at the site. The land needed for the facility is available adjacent to the landfill.

In the event the flow of leachate to the pretreatment process was higher or lower than expected, or pretreatment requirements were increased in the future, parallel process units could be added to increase capacity or effluent quality. A decrease in influent to the process could be handled by process adjustment.

Routine monitoring of potential pathways for migration of effluent and air contaminants would be performed to track the effectiveness of the pretreatment process.

There are no potential problems expected with coordinating with other external agencies for construction and implementation of this facility. Acquisition of building and construction permits would be expected to be routine. A permit will have to be obtained from Des Moines in order to discharge pretreated APL to their system. The Puget Sound Air Pollution Control Authority (PSAPCA) recognizes the ability of the landfill flares to detoxify organic compounds and has permitted their operation at the Midway Landfill. Because of the destructive capability of the flares, and the low volume of air and concentrations of volatile organics and stripped volatile compounds from the leachate pretreatment process being fed to them, no modification to the existin PSAPCA permit would be anticipated.

The implementability rating is high.

The overall rating of Alternative 1 based on the evaluations discussed above is high.

5.2.2 Alternatives 3a, 3b, and 3c

Alternatives 3a, 3b, and 3c are similar except in the area of daily operation. The treatment process, contaminant removal, and process by-products are the same. The evaluation of these three alternatives is combined for the following discussions. Only exceptions related to the differences between the alternatives are addressed separately.

These alternatives involve the same separation of the APL from the NAPL and incineration of the NAPL and volatile compounds discussed in Alternative 1. These alternatives would provide additional pretreatment of the APL in the form of flocculation/sedimentation before the effluent was discharged to Des Moines.

A metal building would be built to house certain process components, including the chemical preparation systems, process controls, and electrical systems. Process controls would be installed throughout the system to shut the operation down in a potential emergency situation. The most significant controls would regulate the well-pumps and pumps from the APL holding tanks.

Operation and maintenance activities would be expanded significantly to operate and maintain the pumps and process units. However, a less rigorous sampling and analysis program would be expected because of the additional pretreatment provided.

5.2.2.1 Overall Protection of Human Health and the Environment

As with Alternative 1, pretreatment of the extracted leachate from the Midway Landfill would reduce the concentration of contaminants related to potential future human exposure through the groundwater system. No current exposure pathways to humans from the Midway contamination exist.

Separation of the extracted APL from the NAPL and pretreatment of the APL would be conducted in enclosed process units to minimize exposure to volatile gases and stripped volatile organics. The volatile compounds would be detoxified in the onsite permitted landfill flares. The NAPL would be permanently detoxified at an offsite permitted facility. Facility workers would follow established health and safety requirements to minimize exposure during routine operation, maintenance, and monitoring activities. Because the effluent discharge to the Des Moines system would attain Metro's pretreatment standards, no additional risk to the Des Moines workers from the Midway effluent would be expected. It would not be anticipated that discharge of pretreated APL to the Des Moines system would inhibit Des Moines from attaining its NPDES permit standards for discharge to the environment.

The rating for overall protection of human health and the environment is high.

5.2.2.2 Compliance with the ARARs

The ARAR for pretreatment of the Midway APL is based on the pretreatment requirements specified by the Metro sewer system. Alternative 3 would provide pretreatment of the APL after it was separated from the NAPL. This APL pretreatment would attain the standards for discharge to the Des Moines system. Attaining the Metro pretreatment limits would allow Des Moines to attain its NPDES permit specifications for discharge to the environment.

The NAPL would be incinerated at a permitted facility. Volatile gases and stripped volatile organics from the pretreatment processes would be incinerated onsite through the permitted landfill flares.

Based on the data from Phase III of the treatability study, dewatered sludge from the pretreatment process would be acceptable for disposal at a local municipal landfill as a solid waste. No differences in the sludge would exist between the Alternative 3 options.

The rating for compliance with the ARARs is high.

5.2.2.3 Long-term Effectiveness and Permanence

Implementation of Alternative 3 at the landfill would not change the contaminants present in the refuse at the site, nor would it remove all the contaminants from the landfill refuse. However, those contaminants that were mobilized into the leachate from water moving through the refuse would be extracted and treated.

Routine upkeep and maintenance of the facility encompassing Alternative 3 would allow it to remain operable and effective. Modifications or additions to the pretreatment facility could be made in order to maintain compliance with potential future changes to the Metro pretreatment standards. No anticipated changes for the incineration of the NAPL would be expected.

The final disposal option for the dewatered sludge may need to be revised if future regulatory changes void the currently planned disposal at a municipal landfill. No changes to the sludge processing would be anticipated to attain potential future disposal requirements. It is not anticipated that the dewatered sludge would lend itself to mobilization in the environment to create a potential future pathway of contaminant exposure.

Alternatives 3a and 3b are manned during operation of most technical processes and rely less on controls to maintain the process than Alternative 3c. This difference is believed to be small and is considered insignificant.

The rating for long-term effectiveness and permanence is high.

5.2.2.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Pretreatment of the Midway leachate would consist of separation of the APL from the NAPL. The PCB-contaminated oil (NAPL) would be permanently detoxified through incineration at a permitted offsite facility. Volatile gases and stripped volatile organics from the pretreatment process would be detoxified through incineration at the onsite permitted flares. The toxicity of the APL would be reduced through the pretreatment process and additional treatment as performed by Des Moines.

The volume of leachate available for offsite transport through the groundwater system would be reduced or possibly eliminated. Therefore, the toxicity and mobility of contaminants that enter the groundwater system would be reduced.

Contaminants transferred from the pretreated APL to the sludge would be contained in a permitted municipal landfill where their mobility would be limited. Based on the Phase III analytical results, the sludge would be classified as a solid waste.

No differences would exist between the Alternative 3 options.

The rating for reduction in the toxicity, mobility, and volume of the contaminants through treatment is high.

5.2.2.5 Short-term Effectiveness

Immediately upon start-up of the pretreatment facility, the toxicity, mobility, and volume of the contaminants from the landfill would be reduced. This pretreatment would result in a reduction in the potential for future exposure of the contaminants to the community through the groundwater pathway.

The pretreatment facility would not create a danger to the public. It would be an aqueous process that is not explosive, flammable, or corrosive. Volatile compounds released from the pretreatment units would be collected and incinerated in the onsite permitted flares. The volatile gases would not create an additional pathway for human exposure to the contaminants. The NAPL would be detoxified at a permitted incinerator. Measures including spill control and health and safety requirements would prevent or minimize the potential for exposure of workers to liquid or gaseous contaminants.

Environmental impacts associated with construction of the facility include noise, dust, and traffic. These impacts are expected to be minimal and could be mitigated by limiting the activity to the site.

No differences would exist between the Alternative 3 options.

The short-term effectiveness rating is high.

5.2.2.6 Implementability

The requirements for construction of this facility would involve common techniques and materials. Problems and delays in the construction would not be anticipated. The types of pretreatment units that comprise this alternative are standard, reliable, and readily available for implementation at the site. The land needed for the facility is available adjacent to the landfill.

In the event the flow of leachate to the pretreatment process was higher or lower than expected, or pretreatment requirements were increased in the future, parallel process units could be added to increase capacity or effluent quality. A decrease in influent to the process could be handled by process adjustment.

Routine monitoring of potential pathways for migration of effluent and air contaminants would be performed to track the effectiveness of the pretreatment process.

There are no potential problems expected in coordinating with other external agencies for construction and implementation of this facility. Acquisition of building and construction permits would be expected to be routine. A permit will have to be obtained from Des Moines in order to discharge pretreated APL to their system. PSAPCA recognizes the ability of the landfill flares to detoxify organic compounds and has permitted their operation at the Midway Landfill. Because of the destructive capability of the flares, and the low volume of air and concentrations of volatile organics and stripped volatile compounds from the leachate pretreatment process being fed to them, no modification to the existin PSAPCA permit would be anticipated.

No differences would exist between the Alternative 3 options.

The implementability rating is high.

The overall rating of Alternative 3 based on the evaluations discussed above is high.

5.3 COST OF THE REMEDIAL ALTERNATIVES

This section provides the detailed cost estimates for each of the remedial alternatives proposed for pretreatment of the Midway APL. These estimates were developed based on EPA guidance for conducting feasibility studies under CERCLA (EPA 1988).

The costs developed here are based on the conceptual designs of the alternatives performed in Chapter 4. As stated in the design assumptions in Section 4.1.2, order-of-magnitude cost estimates for the leachate extraction system and piping and associated equipment necessary to convey the leachate to the pretreatment system, and the piping system for discharge of the pretreated APL to the Des Moines sewer system will be developed in the associated feasibility study.

The estimates include direct and indirect capital costs, and annual O&M costs over the anticipated 30-year treatment period. The present worth of these future dollar expenditures was also determined, and a sensitivity analysis was performed using different discount rates. In accordance with the EPA guidance, the cost estimates developed here are accurate to within -30 to +50% of the planned final project cost for each of the alternatives.

5.3.1 Capital Costs

The major technologies that comprise each alternative conceptually designed in Chapter 4 were used to develop the capital cost of the alternative. The total capital cost of the alternative consists of direct and indirect costs. Direct capital costs are costs associated with items such as construction and installation, specific treatment units, ancillary equipment, and buildings. A summary of the direct and indirect capital costs for each alternative is presented in Table 5.3. An itemized list of the capital costs for each alternative is provided in Appendix E.

Indirect capital costs include such items as administration, engineering, shipping, permits, and sales tax. Other indirect costs include contingency allowances and start-up/shakedown costs. The following assumptions were made in estimating the indirect capital costs for each of the alternatives:

- Administration - 5 - 6% of the total direct cost.

- Engineering - 10 - 15% of the total direct cost, depending on the complexity of the pretreatment system and the ancillary equipment required.

- Shipping - 2% of the total direct cost.

- Permits - 2 - 4% of the total direct cost.

- Sales Tax - Washington State sales tax of 8.1%.

- Contingency - 20% of the total direct cost to account for uncertainties in the cost of the technologies and their implementation.

- Start-up/Shakedown - 2% of the total direct cost, included in the event the process requires adjustments during the initial phases of operation.

5.3.2 Annual Operating and Maintenance Costs

The annual O&M costs were developed based on a determination of the pretreated effluent, NAPL, sludge (if any) disposal requirements, power needs for the process, chemical quantities, analytical and sampling requirements, and maintenance costs.

A summary of the annual operation and maintenance costs for each alternative is presented in Table 5.3. A detailed listing of the items that comprise these costs is provided in Appendix E.

5.3.3 Present Worth Analysis

A present worth analysis is used for annual O&M expenditures over the lifetime of the pretreatment process to determine their equivalent value in today's dollars. This present value of the total cost allows comparison of the alternatives. This total cost would represent the amount of money that would need to be invested today at a given rate of return to provide sufficient funds to cover all expenditures over the life of the process.

The present worth was calculated using the formula:

$$P = \frac{R[(1 + i)^n - 1]}{i(1 + i)^n}$$

Where:

P = the present worth
R = the annual operating and maintenance costs
i = the annual interest rate
n = the planned length in years of the process.

In accordance with the EPA guidance, an interest or discount rate of 5% was used to determine the present worth. The planned life of the pretreatment unit is 30 years. An inflation rate was not used when determining the present worth of the annual O&M costs. An inflation factor would increase the present worth for each alternative. For comparison purposes, the present value for each alternative can be used.

A summary of the present worth of each of the alternatives is presented in Table 5.3.

5.3.4 Sensitivity Analysis

A sensitivity analysis assesses the effect that variations in assumptions associated with the design, implementation, operation, discount rate, and effective life of an alternative can have on the estimated cost of the alternative. These assumptions depend on the accuracy of the data developed during the site characterization and treatability investigation, and on predictions of the future behavior of the technologies. Because these assumptions are subject to varying degrees of uncertainty, the potential effect on the cost of an alternative, or sensitivity of the cost, can be observed by varying the assumptions.

For the pretreatment alternatives developed for the Midway Landfill, the greatest assumptions were made in the length of time the alternative would be operated, and the degree to which the alternative would be operated manually or automatically. These assumptions were varied only for Alternative 3. Alternative 1 was developed with only one specific operational method. Variations in cost within Alternative 3 are presented in Table 5.3. Because the cost estimates were developed to be accurate within -30 to +50%, variations within other design assumptions were not evaluated.

The sensitivity of the present worth of each alternative with respect to the discount rate was also evaluated. The discount rate was varied at levels of 3 and 10%. As summarized in Table 5.3, as the discount rate increases, the present worth of the alternative decreases. This is because less money would be required to be invested at a higher rate of return to provide sufficient funds to cover all expenditures over the life of the process.

5.3.5 Summary of the Estimated Costs

A summary of the estimated costs of the alternatives is presented in Table 5.3. These costs were developed for each of the three Alternative 3 processes, and at discount rates of 3, 5, and 10%. A detailed list of the costs is provided in Appendix E. The summary of costs, along with the evaluation of the alternatives summarized in Table 5.2, will be used in Chapter 6 for comparison of the alternatives.

Table 5.3 Summary of estimated costs.

Criterion	Element	Alt. 1: Oil/Water; Incinerate Gases and NAPL; APL to Des Moines	Alt. 3: Oil/Water; Floc/Sedimentation; Incinerate Gases and NAPL; APL to Des Moines 3a	3b	3c
Direct Capital	Oil/water sep	$ 24,622	$ 24,622	$ 24,622	$ 24,622
	APL storage tanks	$ 0	$ 80,643	$ 0	$ 0
	Ferric tank	$ 0	$ 6,350	$ 6,350	$ 6,350
	Polymer tank	$ 0	$ 5,575	$ 5,575	$ 5,575
	Mixer	$ 0	$ 8,871	$ 5,200	$ 5,200
	Clarifier	$ 0	$110,000	$ 78,000	$ 78,000
	Solids holding tank	$ 0	$ 12,920	$ 12,920	$ 12,920
	Filter press	$ 0	$ 21,000	$ 21,000	$ 21,000
	Venting system	$ 11,320	$ 14,160	$ 14,160	$ 14,160
	Building	$ 0	$300,000	$300,000	$300,000
	Sludge handling	$ 0	$ 15,000	$ 15,000	$ 15,000
	Electrical	$ 2,000	$ 12,000	$ 9,600	$ 10,400
	Instruments	$ 3,000	$ 15,000	$ 18,000	$ 30,000
	Plumbing	$ 5,000	$ 14,000	$ 12,000	$ 12,000
	Installation	$ 20,000	$ 25,000	$ 23,000	$ 23,000
Total Direct Capital		$ 65,942	$665,141	$545,427	$558,227
Indirect Capital	Administration	$ 3,297	$ 33,257	$ 32,726	$ 33,494
	Engineering	$ 9,891	$ 66,514	$ 65,451	$ 66,987
	Shipping	$ 1,319	$ 13,303	$ 10,909	$ 11,165
	Permits	$ 2,638	$ 13,303	$ 10,909	$ 11,165
	Sales tax	$ 5,341	$ 53,876	$ 44,180	$ 45,216
	Contingency	$ 13,188	$133,028	$109,085	$111,645
	Start-up/shakedown	$ 1,319	$ 13,303	$ 10,909	$ 11,165
Total Indirect Capital		$ 36,993	$326,584	$284,168	$290,836
Total Capital		$102,935	$991,725	$829,595	$849,064
Annual O&M	Sludge disposal	$ 0	$ 22,995	$ 22,995	$ 22,995
	Wastewater discharge	$ 52,697	$ 52,697	$ 52,697	$ 52,697
	Analytical/sampling	$ 83,200	$ 41,600	$ 41,600	$ 41,600
	Operator	$ 0	$146,000	$438,000	$146,000
	Polymer	$ 0	$ 2,031	$ 2,031	$ 2,031
	Ferric sulfate	$ 0	$ 29,383	$ 29,383	$ 29,383
	Electrical	$ 66	$ 2,409	$ 4,730	$ 5,256
	General maintenance	$ 8,000	$ 10,000	$ 10,000	$ 10,000
	Maintenance: venting	$ 4,320	$ 4,320	$ 4,320	$ 4,320
	Oil disposal	$ 62,700	$ 62,700	$ 62,700	$ 62,700
	Oil transport	$ 4,400	$ 4,400	$ 4,400	$ 4,400
	Maintenance: o/w sep	$ 0	$ 2,000	$ 2,000	$ 2,000
Total Annual O&M		$215,383	$380,535	$674,855	$383,382
Present Worth	Capital costs	$ 102,935	$ 991,725	$ 829,595	$ 849,064
	O&M 3%	$2,906,347	$6,143,326	$11,912,018	$6,199,127
	5%	$2,279,406	$4,818,123	$ 9,342,425	$4,861,887
	10%	$1,397,864	$2,954,752	$ 5,729,316	$2,981,590
Total Present Worth	3%	$3,070,070	$7,195,839	$12,802,301	$7,108,979
	5%	$2,439,568	$5,867,075	$10,229,247	$5,768,178
	10%	$1,550,896	$3,996,574	$ 6,609,008	$3,880,751

6. SUMMARY AND SELECTION OF THE REMEDIAL ALTERNATIVES

This section presents a summary of the alternatives based on the detailed evaluations and direct and present worth cost analyses performed in Chapter 5. This section briefly describes each alternative and discusses the advantages and uncertainties of each. A ranking of the alternatives is then performed based on the degree to which they would satisfy the evaluation criteria and be cost-effective. The summary and ranking of the alternatives is then used to select the preferred remedial alternative for pretreatment of the Midway APL.

6.1 SUMMARY OF ALTERNATIVES

A summary of the remedial alternatives considered for pretreatment of the Midway APL is presented in Table 6.1. This table lists the advantages of each alternative based on the evaluation criteria performed in Chapter 5. These criteria include overall protection of human health and the environment, compliance with ARARs, long-term effectiveness and permanence of remedial action, reduction of toxicity, mobility, and volume of the contamination, short-term effectiveness of the remediation, implementability, and cost. The cost summary includes the total direct cost of the alternative, and the present worth of the annual O&M costs at discount rates of 3, 5, and 10%.

A brief discussion of the alternatives is provided below:

6.1.1 Alternative 1

This alternative involves separation of the APL from the NAPL and discharge of the APL to the Des Moines system. Des Moines will provide additional treatment of the APL before it is discharged to a surface water body in compliance with Des Moines' NPDES permit. Volatile gases would be incinerated in the onsite permitted flares. The NAPL would be incinerated at an offsite permitted facility.

Extraction of the landfill leachate would occur 24 hours per day, 7 days per week. Controls would be installed between the APL storage tanks and the well-pumps to prevent overflows. The facility would be manned 8 hours per day, and be manually operated 6 of those hours, 7 days per week.

Implementation of Alternative 1 would reduce the concentration of contaminants related to potential future human exposure through the groundwater system. This alternative would reduce the potential for future human exposure to the landfill contamination through the groundwater pathway. The pretreatment process would be effective immediately on start-up of the operation, and would be controlled to minimize exposure to the workers. Alternative 1 would attain the Metro pretreatment standards. The process would use reliable and readily obtainable equipment that could be easily adaptable to maintain future compliance.

Table 6.1. Summary of the detailed evaluations.

Criterion	Alternatives: Alt. 1: Oil/Water; Incinerate Gases and NAPL; APL to Des Moines	Alternatives: Alt. 3: Oil/Water; Floc/Sedimentation; Incinerate Gases and NAPL; APL to Des Moines
Overall Protection Human Health and Environment	Reduces or eliminates leachate available for offsite transport. Incinerate gases and NAPL. Minimal exposure to workers. No additional exposure to Des Moines.	Reduces or eliminates leachate available for offsite transport. Incinerates volatile gases and NAPL. Minimal exposure to workers. No additional exposure to Des Moines.
Compliance with ARARs	Attains pretreatment standards. Incinerate gases and NAPL.	Attains pretreatment standards. Incinerate volatile gases and NAPL. Sludge acceptable to municipal landfill.
Long-Term Effect and Permanence	Would treat mobilized contaminants. Routine maintenance to remain operable and effective. Adaptable to maintain compliance. Gases and NAPL detoxified.	Would treat mobilized contaminants. Routine maintenance to remain operable and effective. Adaptable to maintain compliance. Volatile gases and NAPL detoxified. No changes to sludge processing to attain potential future disposal requirements. Contaminants in sludge not mobile.
Reduction of Toxicity, Mobility, and Volume	Detoxifies gases and NAPL. Reduces toxicity of APL. Reduces or eliminates total leachate volume. Contaminants in sludge contained in municipal landfill. Reduces groundwater contamination.	Detoxifies volatile gases and NAPL. Reduces toxicity of APL. Reduces or eliminates total leachate volume. Contaminants in sludge contained in permitted municipal landfill. Reduces groundwater contamination.
Short-Term Effect	Immediate effectiveness on start-up. No danger to public. Controlled for minimal exposure to workers. Incinerates gases and NAPL. Minimal construction impacts.	Immediate effectiveness on start-up. No danger to public. Controlled for minimal exposure to workers. Incinerates volatile gases and NAPL. Minimal construction impacts.
Implementability	Common techniques and materials. Reliable and readily available. Land available. Routine monitoring. No special permits required.	Common techniques and materials. Reliable and readily available. Land available. Routine monitoring. No special permits required.

Present Worth		Alt. 1	3a	3b	3c
Capital costs		$ 102,935	$ 991,725	$ 829,595	$ 849,064
O&M	3%	$2,906,347	$6,143,326	$11,912,018	$6,199,127
	5%	$2,279,406	$4,818,123	$ 9,342,425	$4,861,887
	10%	$1,397,864	$2,954,752	$ 5,729,316	$2,981,590
Total Present Worth	3%	$3,070,070	$7,195,839	$12,802,301	$7,108,979
	5%	$2,439,568	$5,867,075	$10,229,247	$5,768,178
	10%	$1,550,896	$3,996,574	$ 6,609,008	$3,880,751

No modifications to the existing PSAPCA permit for the landfill flares would be anticipated. A permit will have to be obtained from Des Moines in order to discharge pretreated APL to their system. There would be no expected delays in obtaining the necessary permits for construction and implementation of the alternative pretreatment process.

This alternative has the lowest capital and present worth costs.

6.1.2 Alternatives 3a, 3b, and 3c

This alternative consists of three process options: 3a, 3b, and 3c. These options, discussed below, differ in the length of time the facility would have manned operation each day and the extent to which each operation would be automated.

Each option within Alternative 3 involves separating the APL from the NAPL and further pretreating the APL with flocculation/sedimentation. The effluent from this pretreatment process would be discharged to Des Moines. Des Moines will provide additional treatment of the effluent before it is discharged to a surface water body in compliance with Des Moines' NPDES permit.

Volatile gases and stripped volatile organics from each of the primary pretreatment units would be collected and incinerated in the onsite permitted flares. The NAPL would be incinerated at an offsite permitted facility. Sludge from the pretreatment process would be dewatered and disposed of at a local municipal landfill as a solid waste.

Implementation of any Alternative 3 option would reduce the concentration of contaminants related to potential future human exposure through the groundwater system. These alternatives would reduce the potential for future human exposure to the landfill contamination through the groundwater pathway. The pretreatment process would be effective immediately on operation, and controlled to minimize exposure to the workers. Alternative 3 would attain the Metro pretreatment standards. The process consists of reliable and readily obtainable equipment that could be easily adaptable to maintain future compliance.

No modifications to the existing PSAPCA permit for the landfill flares would be anticipated. A permit will have to be obtained from Des Moines in order to discharge pretreated APL to their system. No problems or delays would be expected in obtaining the necessary permits and modifications for implementation of the pretreatment options under Alternative 3.

A building would be built to house selected equipment, reagents, and electrical controls. The building would be equipped with garage doors for equipment access, and supplied with health and safety gear.

6.1.2.1 Alternative 3a

Extraction of the landfill leachate would occur 24 hours per day, 7 days per week. Controls would be installed between the APL storage tanks and the well-pumps to prevent overflows. The pretreatment process comprising Alternative 3a would be manned 8 hours per day. Of these 8 hours, the process would be manually operated 6 hours per day, 7 days per week with manual and automatic controls.

This alternative has the highest capital costs of the Alternative 3 options. The total present worth costs for Alternative 3a are between those of Alternatives 3b and 3c.

6.1.2.2 Alternative 3b

Extraction of the landfill leachate would occur 24 hours per day, 7 days per week. No APL storage units would be necessary. This process would be manually operated 24 hours per day, 7 days per week. Minimal process automation would be installed.

This alternative has the lowest capital costs and the highest total present worth costs of the Alternative 3 pretreatment options.

6.1.2.3 Alternative 3c

Extraction of the landfill leachate would occur 24 hours per day, 7 days per week. This process would be operated 24 hours per day. Of these 24 hours, the process would be manually operated 8 hours per day, and automatically operated 16 hours per day.

The capital cost for Alternative 3c is between that of Alternatives 3a and 3b. Alternative 3c has the lowest total present worth costs of the Alternative 3 options.

6.2 RANKING OF THE ALTERNATIVES

A ranking of the remedial alternatives proposed for pretreatment of the Midway APL is presented in Table 6.2. These alternatives are ranked according to the degree to which they protect human health and the environment, and are cost-effective. All things being equal, cost was used as the determining factor to rank the alternatives.

Table 6.2. Ranking of the remedial alternatives for pretreatment of the Midway APL.

Alternative	Rank	Description
1	1	Oil/water separation; collection and onsite incineration of volatile gases; collection and transportation of NAPL to permitted incinerator; discharge of the APL to Des Moines. Leachate extraction 24 hours per day, 7 days per week. Facility manned 8 hours per day. Of these 8 hours, the process will be manually operated 6 hours per day, 7 days per week.
3c	2	Oil/water separation in combination with flocculation/sedimentation; collection and onsite incineration of volatile gases and stripped volatile organics; collection and transportation of NAPL to permitted incinerator; discharge of the pretreated APL to Des Moines; dewatering of sludge and disposal at municipal landfill. Leachate extraction and process operation 24 hours per day, 7 days per week. Of the 24 hours of operation, the process would be manually operated 8 hours per day and automatically operated 16 hours per day.
3a	3	Same as Alternative 3c. Leachate extraction 24 hours per day, 7 days per week. Facility manned 8 hours per day. Of these 8 hours, the process would be manually operated 6 hours per day, 7 days per week.
3b	4	Same as Alternative 3c. Leachate extraction and manual operation 24 hours per day, 7 days per week.

6.3 RECOMMENDED REMEDIAL ALTERNATIVE

Based on the detailed evaluations of the remedial alternatives performed in Chapter 5 and the summary and ranking performed as part of this Chapter, **the recommended remedial alternative for pretreatment of the Midway APL is Alternative 1.** This alternative consists of oil/water separation with discharge of the APL to Des Moines for additional treatment. The NAPL would be detoxified at an offsite permitted landfill. Volatile gases from the separation process would be collected and incinerated at the onsite permitted landfill flares.

Alternative 1 is recommended because it would reduce the concentration of contaminants related to potential future human exposure through the groundwater system. Alternative 1 would attain the Metro pretreatment standards. This alternative detoxifies the volatile gases and the NAPL, and reduces the toxicity of the APL. Alternative 1 would be effective immediately on start-up of the process, and uses reliable and readily available materials. Compared with the other alternatives, Alternative 1 has the lowest capital and O&M costs.

In the event Des Moines determines additional pretreatment of the Midway APL would be necessary before discharge to the sewer system, Alternative 3c would be recommended. As with Alternative 1, this alternative would reduce the concentration of contaminants related to potential future human exposure through the groundwater system. The alternative would be effective immediately. Volatile gases and stripped volatile compounds would be detoxified in the existing onsite permitted flares. NAPL would be detoxified at an offsite permitted incineration facility. Dewatered sludge would be acceptable for disposal at a local municipal landfill.

Alternative 3c provides additional pretreatment of the APL in the form of flocculation/-sedimentation. The materials and equipment used in Alternative 3c are reliable and readily attainable. Compared with the other pretreatment options under Alternative 3, Alternative 3c has the lowest total present worth costs.

Alternative 1 and 3c will be carried into the associated feasibility study as the preferred remedial alternatives for pretreatment of the Midway APL. A selection between these alternatives can be made when Des Moines determines which pretreatment effluent would be acceptable for discharge to the Des Moines sewer system.

6.4 UNCERTAINTIES

There are two major concerns regarding the treatment of the APL at Midway. The first concern is the uncertainty regarding the characteristics of the APL. The second concern is the possibility that the pretreatment limits set by Metro will be lowered in the future. These two uncertainties can be remedied, if necessary, by modification of the treatment process.

The extensive sampling performed onsite, including FS Round 4 (Treatability Study samples and Ecology splits) which confirmed previous results, provides confidence in the general makeup of the APL (AGI 1990). We feel that the process train described here will provide adequate treatment of the APL. The treatment process can be chemically modified and/or another treatment unit, such as carbon adsorption, can be added to further clean up the APL.

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REFERENCES

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Appendix A

Work Plan

MIDWAY LANDFILL FEASIBILITY STUDY
TREATABILITY STUDY REPORT

WORK PLAN

Prepared for

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INTRODUCTION

The City of Seattle, with assistance from Parametrix, Inc. is performing cleanup and closure operations at the Midway Landfill in south King County. These operations include the development of a feasibility study evaluating groundwater, surface water, seeps, and soil pathways of exposure to contaminants associated with the landfill.

A feasibility study determines the extent to which remedial actions mitigate or minimize present and future human exposure, or the pathways of exposure, to the contamination characterized in the remedial investigation. Based on the information presented in the feasibility study, the most appropriate and cost-effective remedial actions are then selected.

Groundwater contamination, in part due to leachate generated at the site, has been detected beneath the landfill surface. Leachate is generated when water or other liquid enters the landfill or is present in the waste and contacts the buried refuse. While biological decomposition produces small quantities of water, infiltration and inflow from rainfall and surface water run-on are the more significant sources. Because leachate can become contaminated if landfill wastes contain contaminants that may be dissolved or suspended in the liquid, it poses a threat to groundwater if no artificial or natural barriers to the flow exist.

Sampling of the monitoring wells within the boundaries of the Midway Landfill have indicated that two leachate phases exist: nonaqueous and aqueous. The nonaqueous phase liquid (NAPL) is an oily, highly viscous, odoriferous liquid. The NAPL has been found in 12 onsite gas extraction wells. In all 12 wells, the NAPL was found to be a layer floating on top of the aqueous phase leachate (APL).

Analysis of the NAPL has shown it to contain both volatile organic compounds (VOCs) and polychlorinated biphenyls (PCBs). The APL contains elevated levels of VOCs and PCBs. However, these concentrations are orders of magnitude less than those found in the NAPL.

Because of the elevated concentrations of PCBs in the NAPL, and due to its apparently limited presence beneath the landfill and its ease of separation from the aqueous phase, the NAPL will not be treated prior to final discharge. Rather, the NAPL will be extracted from the wells when encountered, and transported to a permitted offsite incinerator in accordance with the Department of Transportation (DOT) and Toxic Substance Control Act (TSCA) regulations (Parametrix 1989).

In previous meetings with SAIC, AGI, and Enviros, technologies potentially applicable to treating the APL at Midway have been identified and screened. However, because leachate is highly variable at different landfills, it is difficult to predict which treatment technologies would be most appropriate. Because of this, a treatability study using APL samples from the Midway site was recommended.

PURPOSE

The purpose of the treatability study is to bench test applicable treatment technologies and processes to identify which are technically and economically feasible for implementation at the Midway Landfill. A specific treatment process will be recommended, designed, costed, and carried through the Midway feasibility study.

Identification of the technically feasible processes requires experiments conducted under conditions appropriate to the characteristics of the leachate. Key design parameters are needed to estimate costs of pilot-scale and full-scale treatments systems. Because treatment of landfill leachate is a relatively new area of wastewater treatment and leachates are highly variable at different landfills, it is difficult to predict which treatment technologies would be most appropriate. Therefore, treatability studies are required using actual samples of leachate from the Midway Landfill to obtain applicable information.

The goal of the aqueous leachate treatment process will be to produce an effluent of suitable quality for discharge to the Des Moines Sewer District system. Des Moines will perform final and permanent treatment of the Midway liquid before discharging it to the environment in compliance with their National Pollutant Discharge Elimination System (NPDES) permit. In order to satisfy Metro's discharge limitations, the leachate must be treated to reduce free oil, VOCs, PCBs, and possibly heavy metals and other compounds.

No attempt will be made during the treatability study to enhance the performance of the technologies or processes being examined. Such optimization will be performed during future pilot-scale studies as necessary. However, realizing that Metro standards will change, the process string most appropriate for treating the aqueous leachate at Midway that can attain Metro discharge standards will be tested to determine the level to which these standards can be surpassed.

TREATMENT LEVELS FOR AQUEOUS LEACHATE

Treatment levels required for discharge to a Metro sewer line are not precisely defined for all contaminants in landfill leachate. One purpose of the treatability study is to determine the treatment levels attainable using different processes. Nevertheless, preliminary treatment goals may be established to measure the relative efficacy of different options.

The following are the preliminary treatment goals for contaminants found in the Midway leachate:

- PCBs: 0.5 mg/L
- VOCs: 10 μg/L
- Arsenic: 1.0 mg/L
- Cadmium: 0.5 mg/L
- Chromium: 2.75 mg/L
- Copper: 2.0 mg/L
- Lead: 1.0 mg/L

- Nickel: 2.0 mg/L
- Fats, oils, and grease: 100 mg/L.

The treatment goal specified above for PCBs is Metro's current standard for treated waste from a local treatment, storage, and disposal facility. The goal for VOCs is based on a working knowledge of treatment technologies and their ability to achieve cleanup levels when implementation and maintenance costs are considered. The treatment goals for metals are the maximum specified by Metro for discharge into their sanitary sewer system. Technologies that cannot at least attain the goals listed above will not be considered for leachate remediation at Midway.

TREATMENT TECHNOLOGIES AND CONCEPTUAL PROCESS TRAINS

There are numerous technologies that may be used to treat wastewater similar to landfill leachate. It is critical to consider the treatment goals and the properties of the leachate when screening these technologies. At the Midway Landfill, PCBs and VOCs are the principal compounds of concern. There is also some oil present in the leachate, however, this will be removed and disposed of as previously discussed.

A significant amount of PCBs are present in the Midway APL in quantities greater than would be predicted from their solubility in water. This observation has led to the idea that the high concentration of surfactants in the APL is responsible for the elevated PCBs. Thus, removal of PCBs could be tied to the removal or breakdown of the surfactants. The surfactants may also be associated with some of the VOC contamination.

The following water treatment technologies are most likely to be technically and economically feasible for treating APL at the Midway Landfill:

- Oil/water separation, followed by incineration of the oil and water treatment
- Flocculation/sedimentation, followed by additional treatment, if needed
- Froth flotation, followed by additional treatment, if needed
- Ultrafiltration, possibly to remove PCBs
- Granular activated carbon, if needed, to remove residual PCBs and VOCs
- Aeration, if needed, to remove residual VOCs
- Ozone/UV or peroxide/UV, if needed, to remove residual PCBs and VOCs.

While the level of treatment obtainable by these technologies is uncertain, oil/water separation must be the first treatment step. Free oil will interfere with the other treatment technologies. Although oil and water separation is a well-established technology, this process will be evaluated during the treatability study for separation of NAPL from the APL. As part of the final process string, an oil/water separator will be conceptually designed and costed.

Flocculation/sedimentation and froth flotation may provide significant removal of the compounds of concern. It is not known whether these methods will provide sufficient treatment alone or whether follow-up treatment will also be needed. Therefore, a phased approach to the treatability study will be performed.

The first phase will be the testing of flocculation/sedimentation and froth flotation. If these technologies provide adequate pretreatment alone, no second-phase experiments will be performed. If follow-up treatment is needed, then the remaining technologies will be tested. The third phase experiments will combine the most appropriate technologies identified in Phase I and II into a process string. Fresh leachate will be run through this string in order to evaluate the variability of the effluent quality, as well as determine the extent to which the Metro treatment goals have been surpassed.

LEACHATE SAMPLE PREPARATION

A representative leachate sample is required for the treatability studies. No sample can be perfectly representative because of the variability of the composition of the leachate over time and between different leachate wells. Nevertheless, volumetrically-equal samples of leachate will be taken from each of eight wells and combined.

A total volume of approximately 160 liters will be collected for the treatability studies. Bulk samples will be stored in amber glass containers at 4° C. Similar glass containers will be used to store composite leachate samples to be used in the study. The containers are certified pre-cleaned by the manufacturer. Preparation of a fresh composite leachate sample will entail the following procedure:

- Prepare 32 liters of sample at a time, four liters from each well, to prevent head space in the containers
- Shake or rotate the containers holding leachate from each specific well to ensure uniformity of the contents
- Draw equal volumes, approximately 500 ml, from each of the eight well-specific leachate containers
- Combine the samples in a four-liter amber glass container
- Shake or rotate the container to mix the contents
- Mix or rotate the container before withdrawing each test sample.

QUALITATIVE EXPERIMENTS

Several effective treatment technologies have been identified for removing contaminants of concern from Midway leachate. To expedite the treatability studies, qualitative experiments are planned to observe general properties of the leachate. Aeration, flocculation/sedimentation, and froth flotation will be examined briefly. Properties and results will be noted. These qualitative properties include the formation of a well-settled floc, the partitioning of distinct phases, the formation of a stable foam, the clarity of supernatant or filtrate, the effect of pH adjustment, and the effect of aeration. The observations from these qualitative experiments will allow better configuration of the Phase I treatability studies and may indicate that certain technologies are not usable.

PHASE I TREATABILITY STUDIES

Phase I treatability studies are intended to evaluate the efficacy of leachate treatment processes. One of the major intentions of the phase I studies is to determine the treatment levels achievable with these processes and obtain estimates of operating parameters. These studies will also determine if follow-up treatment is needed.

Because of the uncertainties in the treatment effectiveness of the different technologies, it is impossible to predict the course of experiments required in a treatability study. General procedures are outlined below, but the direction of experimentation depends on the results of previous experiments. In some cases, it may not be possible to determine the conditions suitable for the success of a particular technology within a reasonable amount of time. In other cases, successful operation may be identified after the first test.

Froth Flotation

Description of Process. Froth flotation is a method of removing fine particulates, surfactants, oils, and dissolved chemicals from water by sorbing the materials onto a foam or froth that rises to the surface of a tank or column of water. The foam is formed by vigorous aeration from the base of the tank. The resulting foam is skimmed from the top of the tank and treated separately.

A foaming agent may be added to the solution by the process operator or it may be present in the wastewater as part of the waste stream (such as commercial detergents). By selecting among cationic, anionic, and neutral foaming agents, it is possible to control which chemicals are removed from the solution and the amount of liquid in the foam.

The goal of the present study is to create a neutral foam that will remove oils, PCBs, and colloidal metal oxides and hydroxides. The aeration step will have the added benefit of removing a large percentage of VOCs and surfactants.

Key Parameters of Interest:

- Dose and type of foaming agent
- Removal efficiencies of oil, PCBs, metals, and VOCs

- Aeration requirements (air flow rate, air to liquid volumetric flow ratios, liquid area to volume ratios)
- Quality and volume of froth produced
- Solution pH (major effect on formation of metal oxide colloids).

Equipment, Supplies, and Reagents:

- Laboratory air supply
- Air flow meters
- Aeration vessels (250 ml) with gas diffusers at base
- Neutral foaming agents per vendor recommendation
- Concentrated sodium hydroxide and sulfuric acid solutions.

Brief Description of Experiments:

- Experimentation flowchart (Figure 1)
- Identification of foaming agents and dose
- Determination of aeration conditions
- Determination of effect of pH on foam quality and metal precipitation
- Determination of overall removal efficiency and mass balance calculations for chemicals of concern.

Number of Experiments Anticipated:

- Forty experiments to establish physical quality of foam
- Three experiments, run in triplicate, to establish chemical quality of foam and water.

Product of Phase I Experiments:

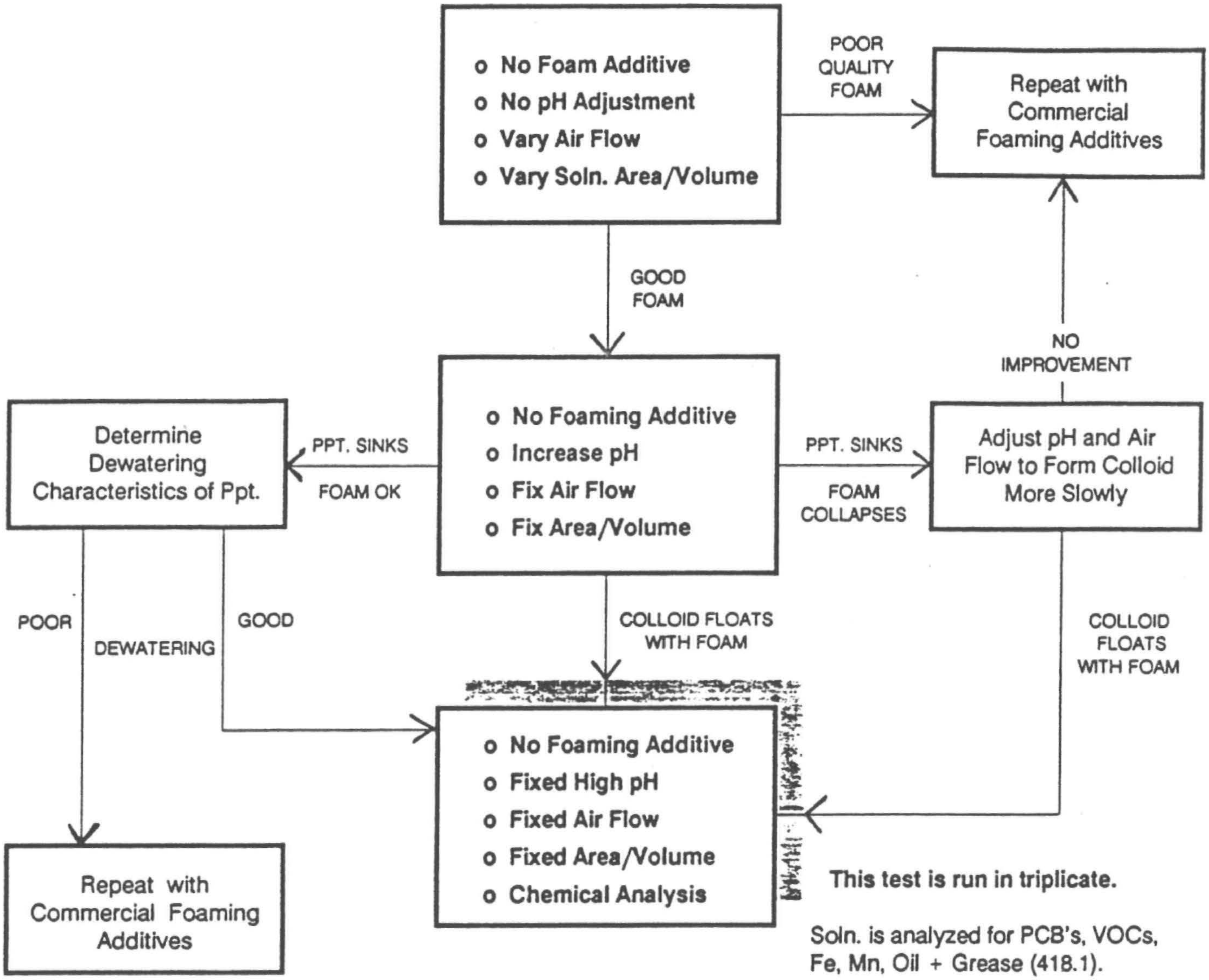
- Determination of treatment efficiency and possible need for follow-up treatment
- Determination of representative operating parameters for estimation of pilot and full-scale design parameters and cost.

Possible Follow-Up Experiments:

- Removal of trace levels of PCBs and VOCs
- Reduction of dose to obtain same level of contaminant removal
- Testing with different frothing agents to improve contaminant removal efficiency.

Chemical Analyses:

- PCBs in water
- Purgeable halocarbons in water
- Purgeable aromatics in water



This test is run in triplicate.

Soln. is analyzed for PCB's, VOCs, Fe, Mn, Oil + Grease (418.1).

Foam is analyzed for PCBs and VOCs.

(Ppt. is analyzed for PCB's and VOCs)

Volumes of each phase are carefully measured for cost analysis.

This whole scheme is repeated with two commercial foaming additives. The dose of the foaming agent is varied in step one until a good foam is produced.

A good foam is one which rises to surface without scum buildup on tank sides, which can be removed by suction or skimming, which collapses easily, and which results in a low volume of condensed fluid or solid.

Figure 1

Foam Flotation Experiments

Midway Landfill Treatment Studies

- Heavy metals, water
- PCBs in foam
- Purgeable halocarbons in foam
- Purgeable aromatics in foam
- PCBs in precipitate
- Purgeable halocarbons in precipitate
- Purgeable aromatics in precipitate.

Flocculation/Sedimentation

Description of Process. Flocculation/sedimentation involves the addition of coagulating and flocculating chemicals to agglomerate suspended particles and capture certain dissolved compounds. Once the "floc" is formed, it may be removed by settling or flotation under quiescent conditions.

Key Design Parameters of Interest:

- Type of coagulant/flocculent chemicals
- Dose of coagulant/flocculent, g/L or lb/1,000 gal
- Acid/base requirements to reach operating pH, meq/L
- Settling rate of floc, ml of settled floc/L of initial solution/hr
- Hydraulic loading rate of leachate, gpm or MGD
- Cross-sectional area of clarifier or flotation tank, sq ft or sq m
- Solids mass loading to clarifier or flotation tank, lb/sf/d
- Quantity of sludge produced, lb/1,000 gal or g/L
- Solids fraction of sludge, mg/L
- Removal efficiency of PCBs and VOCs, percent removal and final concentration, mg/L.

Equipment, Supplies, and Reagents:

- 400-milliliter pyrex beakers
- Bentonite, $FeCl_3$, and alum
- Flocculent chemicals per vendor recommendations
- Stirring rods or gang stirrers
- pH meter
- Timer
- Concentrated nitric acid and sodium hydroxide solutions
- Graduated cylinder or Ihmhoff cone
- Air supply, flowmeter, air diffuser.

Brief Description of Experiments:

- Flowchart of experimentation (Figure 2)
- Addition of coagulants and flocculants to batches of leachate to observe removal efficiency, repeating with different additives and doses
- Base and acid addition under same conditions to observe effect of pH

Figure 2

Plan of Experimentation
Flocculation/Sedimentation

1. Evaluation of Flocculent Types and Dosages

Three flocculents (alum, bentonite, FeCl3), five doses each: observe removal of foam and residue

Analyze selected samples for PCBs, heavy metals in supernatent

↓ Select most promising flocculents, doses

2. Evaluate effect of pH on performance

Select samples, assess performance at three to four different pH values;

Quantify acid/base requirements (titration curve);

Analyze selected samples for PCBs, heavy metals

↓ Select pH giving best removal

3. Evaluate Impact of Preaeration on Performance

Select promising baseline operating conditions (flocculent, dose, pH);

Preaerate leachate sample;

Quantify change in removal of PCBs, Fe, Mn, heavy metals;

Repeat using different aeration rates and configurations.

↓ Select most promising flocculent, dose, pH, aeration configuration

4. Evaluation of Sludge Properties

Determine settling rate;

Quantify solids concentration of settled sludge;

Evaluate different polymers according to improved solids settling;

TCLM test on selected sludge sample;

Determine sludge volume and mass

- Quantification of sludge production and settling rates from successful treatment processes
- Effect of aeration on coagulation performance and contaminant removal.

Number of Experiments Anticipated:

- Three to five experiments for each of the three flocculants
- Effect of pH on treatment
- Settling tests on one to two promising processes
- Three to five tests incorporating aeration.

Product of Experiments:

- Removal efficiency of contaminants vs. flocculent type and dose
- Solids production rate and solids content of sludge
- Preliminary equipment sizing data.

Possible Follow-Up Experiments:

- Improvement of operating conditions to increase contaminant removal
- Downstream treatment to remove residual VOCs and PCBs.

Chemical Analyses:

- PCBs in water
- Purgeable halocarbons
- Purgeable aromatics
- Heavy metals.

PHASE II TREATABILITY STUDIES

Phase II treatability studies will be conducted if it is demonstrated that the Phase I technologies do not provide complete pretreatment or if the economics appear unfavorable. Fresh effluent from the most applicable Phase I technology will be used as the feed stream for Phase II. Phase II involves further treatment of the APL with ultrafiltration, peroxide/UV, granular activated carbon, and aeration.

Ultrafiltration

Description of Process. Ultrafiltration is a process using a semipermeable membrane to remove particulates or high molecular weight compounds from wastewater. Wastewater or leachate is pressurized and forced along a filter with small pore spaces, forcing water and low molecular weight compounds through the filter. Contaminants and particulates are concentrated as wastewater is recirculated through the ultrafilter. A concentrated liquid is produced which must be further processed and treated. Compounds are not easily removed if they are dissolved and of low molecular weight, although the presence of larger compounds or particulates may improve the removal of these compounds.

Key Parameters of Interest:

- Concentrating factor, percent volume reduction
- Filter membrane type
- Operating pressure, psi
- Filter surface area, sq ft or sq m
- Contaminant removal efficiency, percent removed and remaining concentration, mg/L.

Equipment, Supplies, and Reagents:

- Ultrafiltration test unit and filters
- Two five-gallon covered tanks or carboys
- One one-gallon flask.

Brief Description of Experiments:

- Circulation of leachate through ultrafilter test unit, measuring filtrate production rate, volume reduction of leachate, and effluent quality
- Repeat tests using different filter membranes.

Number of Experiments Anticipated:

- Three experiments: one with each of three different filters.

Product of Experiments:

- Removal efficiency of contaminants
- Preliminary equipment sizing and filter type.

Possible Follow-Up Experiments:

- None recommended.

<u>**Peroxide/UV**</u>

<u>**Description of Process**</u>. Peroxide/UV uses a chemical oxidant and ultraviolet light to oxidize organic compounds to carbon dioxide and water. Wastewater is passed through a chamber and mixed with hydrogen peroxide; the mixture is irradiated with high energy ultraviolet light. To pass the light, the chamber is constructed of quartz glass. The process is capable of oxidizing virtually any organic compound under the correct conditions. However, because the method is non selective, all organic compounds present will be attacked. Also, the process works best when treating dilute solutions. Therefore, peroxide/UV will be used as a post treatment step after the bulk of the organic compounds have been removed in a preliminary treatment step.

Key Parameters of Interest:

- Chemical oxidant dosage
- Contact time
- PCB and VOC removal efficiencies.

Equipment, Supplies, and Reagents:

- Fume hood
- UV reactor with internal lamp and power supply, quartz reaction vessel, and completely shielded light source
- 35 percent hydrogen peroxide.

Brief Description of Experiments:

- Flow cell UV reactor with variable flow rate; different oxidant doses and flow rates will be tested.

Number of Experiments Anticipated:

- Three oxidant dose levels and three total flow rates: six experiments
- Optimum flow rate and dose level from the above experiment will be run in triplicate for the detailed chemical analysis.

Product of Experiments:

- Contaminant removal efficiencies
- Contact time and chemical oxidant doses
- Preliminary equipment sizing data.

Possible Follow-Up Experiments:

- Improved operational parameters to reduce cost for certain level of treatment.

Granular Activated Carbon

Description of Process. Treatment using granular activated carbon (GAC) is conducted by passing wastewater through a vessel packed with GAC. The contaminants bind to the surface of the GAC. Binding depends on the type of contaminant, the type of GAC, and the characteristics of the wastewater. PCBs and VOCs generally adsorb well to GAC. Other compounds present in the leachate may also adsorb to the GAC, reducing its capacity to capture the compounds of interest. Periodically, the GAC must be removed and replaced. The GAC is "regenerated" by heating the carbon to remove the contaminants.

Key Parameters of Interest:

- Removal efficiency of contaminants of interest, percent removal and residual concentration, mg/L
- Amount of carbon needed to achieve desired removal, lb/1000 gal.

Equipment, Supplies, and Reagents:

- Granular activated carbon and powdered activated carbon
- Stirring apparatus
- Drying oven and desiccator
- Filtration equipment
- pH meter
- Tubing and miscellaneous glassware.

Brief Description of Experiments:

- Batch testing of activated carbon with leachate
- Mixing of activated carbon with leachate
- Measurement of adsorption at different concentrations of leachate and activated carbon
- Plot contaminant and carbon concentration and carbon data according to Freundlich isotherm using log-log paper.

Number of Experiments Anticipated:

- Ten batch samples in two separate experiments.

Product of Experiments:

- Contaminant removal efficiencies
- Freundlich isotherm
- Carbon consumption rate.

Possible Follow-Up Experiments:

- None recommended.

Aeration

Description of Process. Aeration is the release of air into the bottom of a tank or tower containing wastewater to remove volatile compounds. Aeration may be successfully used to remove compounds that are volatile, including VOCs but excluding PCBs, provided that the compounds of interest are not strongly bound to other compounds in the leachate.

Key Parameters of Interest:

- Contaminant removal efficiencies
- Air to liquid flow rates
- Contact time
- Possible fouling or scaling.

Equipment, Supplies, and Reagents:

- Small compressor or lab air supply
- Air-flow meters and regulator
- One-liter vessel with air diffuser in base
- Liquid peristaltic pump
- Liquid flowmeter
- Air stripper packing.

Brief Description of Experiments:

- Pumping of leachate through tower or tank with countercurrent flow of air, measuring contaminant removal under different liquid and air flow rates.

Number of Experiments Anticipated:

- Two tests with vessel containing no packing
- Two tests with packed tower model.

Product of Experiments:

- Air to liquid flow rates
- Contact time
- Preliminary equipment sizing data
- Conceptual information on equipment type and removal efficiencies.

Possible Follow-Up Experiments:

- None recommended.

PHASE III TREATABILITY STUDIES

Technologies from Phase I and II most applicable to the APL at Midway will be combined into a process string and evaluated in Phase III. Fresh composite leachate will be used and run through the process string in triplicate to evaluate the variability of the effluent quality, as well as to determine the extent to which the Metro discharge standards have been surpassed.

EXPANDED CHEMICAL ANALYSIS OF LEACHATE

Much of the chemical analysis associated with the treatability studies will focus on the PCBs and VOCs. These compounds will be analyzed to monitor the efficacy of the treatment units. A full characterization of the leachate is also necessary to determine overall treatment effectiveness, but repeatedly analyzing for all contaminants is unnecessary and costly. Full chemical characterizations will be performed on the initial leachate samples and on treated effluent from the Phase III treatment process. Chemical analyses will include priority pollutant scans.

PRELIMINARY PROCESS EVALUATION

Subsequent to conducting the treatability lab tests, it is necessary to evaluate the results to determine the process configuration and cost for a full-scale system. The evaluation of the results requires engineering calculations, product research, and cost analyses to determine the most favorable process. A pilot-scale process will probably be required at a later date.

The preliminary process evaluation requires assimilation of treatability test results, calculations for equipment sizing, preparation of conceptual designs, estimation of major capital and operating costs, and comparison of costs and technical performance of the different options. The preliminary process evaluation will allow recommendation of a single treatment process to be carried through the associated feasibility study. It will also lead into pilot-scale and full-scale design of the leachate treatment system at Midway.

PROGRESS MEETINGS AND PRESENTATION OF FINDINGS TO THE CITY OF SEATTLE

Meetings will be held to prepare work plans, discuss results of the treatability studies, discuss recommendations, and present the findings to the City of Seattle project managers. It is anticipated that nine meetings will be held involving four members of the project team. Three of these meetings will also include other members of the team.

DELIVERABLES

Documentation will be recorded to detail the progress and strategy of the treatability study. This documentation will ultimately justify the recommendations and selections of technologies comprising the final treatment string. The documentation will include reports of findings, observations, analytical results, and conclusions for each phase of work conducted during the study, minutes of meetings conducted before, during, and after each phase, and a treatability study report (Table 1). The phase documentation, excluding meeting minutes, will be included as an appendix to the treatability report.

Table 1. Products of the Midway Landfill aqueous leachate treatability studies.

Qualitative Phase:

> Report - findings, observations, and conclusions.
> Meeting notes - discussion and conclusions.

Phase I:

> Report - findings, observations, analytical results, and conclusions.
> Meeting notes - discussion and conclusions.

Phase II:

> Report - findings, observations, analytical results, and conclusions.
> Meeting notes - discussion and conclusions.

Phase III:

> Report - findings, observations, analytical results, and conclusions.
> Meeting notes - discussion and conclusions.

Treatability Study Report:

> Identification and screening of technologies and alternatives.
> Conceptual design/costing of proposed treatment string.
> Appendices - Workplan, Qualitative, Phase I, II, and III studies.

The treatability report will describe and screen technologies and alternatives identified as potentially applicable for treatment of the Midway APL, and conceptually design and cost the proposed treatment string evaluated during Phase III of the study. The report will be issued to the City of Seattle in preliminary draft, draft, and final form. The final treatment string will be carried through the associated feasibility study as the most applicable treatment process for the APL at the Midway Landfill.

Appendix B

Qualitative Analysis

MIDWAY LANDFILL FEASIBILITY STUDY
TREATABILITY STUDY REPORT

QUALITATIVE ANALYSIS

INTRODUCTION

The initial phase of the treatability studies is designed to qualitatively evaluate the characteristics of the leachate under processing conditions. The Midway aqueous phase leachate (APL) will be subjected to frothing and frothing agents, aeration, and flocculating conditions and agents to determine if these technologies are potentially capable of treating leachate at the landfill. Those technologies determined to be capable of treating the Midway APL will be retained for further evaluation in Phase I of the treatability studies.

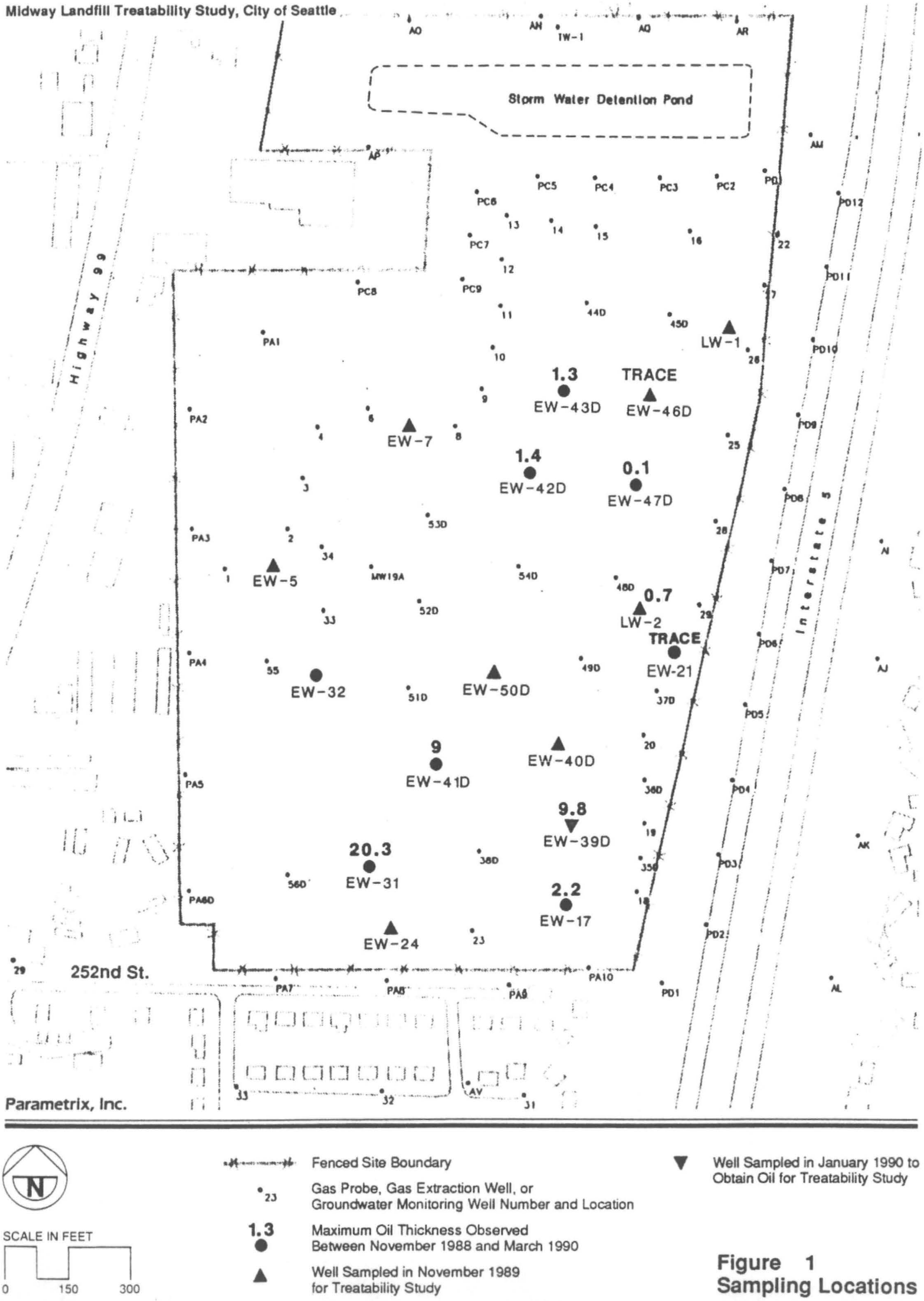
No attempt will be made during the qualitative phase of the treatability study to optimize the technologies or processes being examined. This optimization will be performed during later phases of the study as well as future pilot-scale studies as necessary. No samples will be taken or analyzed during this qualitative phase of work.

SAMPLE PREPARATION

The location of eight wells from which leachate samples were taken from the Midway Landfill is shown in Figure 1. These wells were considered to be representative of the aqueous leachate present at the site. These wells were chosen for the following reasons:

- They are single phase wells (no nonaqueous phase leachate [NAPL]) but are close enough to wells containing NAPL to be possibly influenced by the presence of the oil.
- They contain at least five to ten feet of water and can easily be sampled using dedicated pumps.
- They have specific conductances that are near or above average for landfill leachate at Midway.
- They reasonably span the area of the landfill.

A total of 160 liters of aqueous leachate (20 liters from each well) was collected from the eight landfill wells. The bulk samples were stored in amber glass containers at 4° C at the Enviros, AGI, and ATI laboratories. Similar glass containers and conditions were used to store composite leachate samples. The containers were certified pre-cleaned by the manufacturer.



Parametrix, Inc.

Figure 1
Sampling Locations

To prevent the loss of organic and inorganic contaminants present in the leachate, care was taken to minimize head space in the containers. However, air was introduced into the system when the containers were rotated or shaken to assure uniformity of the contents before composite samples were prepared or test samples withdrawn. Despite the potential for loss of some contaminants in the composite samples during the mixing process, this method was used because it could likely mimic actual processing conditions.

Also, little care was taken to not exceed sample holding times as this could also mimic actual conditions. Once the most applicable treatment string is identified for the aqueous leachate, fresh leachate from the landfill will be run through the system in triplicate to examine the variability of the effluent quality, and the degree to which the process can surpass the discharge standards.

Consistent with the treatability study workplan, fresh composite leachate samples were prepared as follows:

- Thirty two liters of sample were prepared at a time, 4 liters from each well, to prevent head space in the containers.
- The containers holding leachate from each well were shaken or rotated to ensure uniformity of the contents.
- Equal volumes of approximately 500 ml were drawn from each of the eight leachate containers.
- The sample volumes were combined in a four liter amber glass container.
- The containers were shaken or rotated to mix the contents.
- The containers were shaken or rotated before withdrawing each test sample.

Observations made of the aqueous leachate from the eight wells during the composite mixing procedure are as follows:

LW-1: Brown tint, moderate amount of sediment.

LW-2: Medium gray, some sediment present.

EW-5: Clear to pale brown.

EW-7: Clear to light brown, slight amount of solids present, oil sheen on top.

EW-24: Fairly clear to pale green.

EW-40D: Gray with some sediment present, slight oil sheen on top.

EW-46D: Medium gray, some sediment present.

EW-50D: Light gray (darker than EW-5), some sediment present.

FINDINGS AND OBSERVATIONS

FROTH FLOTATION

Froth flotation is a method of removing fine particulates, surfactants, oils, and dissolved chemicals from water by sorbing the materials onto a foam or froth that rises to the surface of a tank or column of water. The foam is formed by vigorous aeration from the base of the tank. The resulting foam is skimmed from the top of the tank and treated separately.

Leachate from Midway was known to contain natural foaming agents. The qualitative experiments were designed to determine if the natural foaming action could be used constructively in treatment of the leachate. Artificial foaming agents were used during the qualitative experimentation to add to the aqueous leachate solution. By selecting among cationic, anionic, and neutral foaming agents, it may be possible to control which chemicals are removed from the solution and the amount of liquid in the foam.

The goal of the froth flotation process is to create a neutral foam that will remove oils, PCBs, and colloidal metal oxides and hydroxides. Aeration, necessary to generate the foam, will have the added benefit of removing a large percentage of volatile compounds, and possibly surfactants in the solution.

The following is a discussion of the procedure and observations made during the qualitative froth floatation experiments involving aqueous leachate from the Midway Landfill:

Leachate With No pH Adjustment (pH Approximately 7)

The composite leachate sample was a gray-tan color with suspended solids. 150 ml of leachate was added to a frothing cylinder for a total leachate height of 8 cm. A horizontal air diffuser was added and air introduced to the system (airflow rate was not measured during this phase of experimentation). The froth height was maintained at 16 cm for five minutes with no airflow adjustments. The froth was mostly clear with some sediments and a small amount of oil on top.

The airflow was increased after five minutes and the froth height increased to 20 cm where it remained for five minutes. Froth height could not be increased despite additional increases in airflow. The airflow was stopped, and the froth collapsed to the original 8 cm of liquid. Refrothing of the leachate generated foam again, indicating that most of the surfactants present in the leachate are not volatile.

An additional 150 ml of leachate was added to the container for a total leachate column height of 13 cm. A proportional column height to liquid volume was not achieved due to variances in the column diameter and attenuation of foam to the sides of the container. Airflow was started again and a definite reflux zone was observed in the froth. A foam sample above the reflux zone was removed. Foam from this sample immediately collapsed. The foamate had a slight gray color and less turbid than the leachate. After five minutes of aeration, the foam height remained at 41 cm. Airflow was increased, but the foam height remained at 41 cm. Foam at the top began breaking up due to the excessive airflow rate. The airflow was decreased until height of leachate and foam was maintained at 13 cm.

The foam readily collapsed when the airflow was stopped. The leachate was more turbid than before. Two foam samples were extracted at 3-minute intervals. Foam in both samples collapsed immediately. Both samples had a light gray color, the first being slightly darker. Both samples had particulate matter in the solution and on the sides of the container.

Ten ml of 1-molar sodium hydroxide was added to the leachate and aeration continued. No immediate change in the foam quality or height was observed. The foam contained more solids at top than before, possibly due to the previous oil sheen that had broken down. Foam samples were taken after two minutes. The foam collapsed easily and was the same color as before. Fresh leachate was added to the samples, but no phase separation was observed. A fine black sediment in the two foam samples was observed, possibly due to the addition of fresh leachate. This sediment was also observed at the bottom of the frothing cylinder and on the air diffuser.

An additional 11 ml of sodium hydroxide was added to the cylinder. The aqueous phase was more brown in color than the previous gray. The foam contained a tan-brown precipitate. More black precipitate was noted at the bottom of the frothing cylinder and on the air diffuser. The leachate turned an orange-brown color, and particles formed and settled to the bottom. The solution was allowed to settle, and three phases formed: A thin black, slick-looking layer on top; a brown-orange aqueous phase with floc; and an orange-brown precipitate at the bottom (possibly iron +3).

The brown-orange aqueous phase was extracted and aerated. Foam was removed as it was generated. After five minutes of aeration, the aqueous phase appeared unchanged. The foam collapsed immediately on removal and had a pale gold color.

The precipitate that formed upon the addition of sodium hydroxide continued to settle in both aerated and non-aerated leachate samples. The precipitate formed a gray-brown gelatinous mass on the bottom of the cylinder, while the remaining solution had an orange-gold color.

Concentrated nitric acid was added to a fresh leachate sample for comparison to addition of sodium hydroxide. Turbidity in the acidic leachate sample decreased, while foam production increased upon shaking of the container. The foam appeared drier than at a basic pH, and did not readily collapse.

Leachate With Adjustment to Basic pH

Leachate with a slight oil sheen on top was adjusted with sodium hydroxide until a pH of 9 was achieved. The mixture was aerated for approximately 18 minutes and a foam sample removed. The foam had a slight oil sheen and collapsed immediately. The foamate pH was 9 and the solution pH was 9.5. The froth bubbles during aeration were very large and apparently wet since they collapsed quickly. Froth height was easily maintained throughout the aeration period.

Aeration was stopped, and the same fine black particulates observed in the non-pH adjusted leachate were noted at the bottom of the frothing cylinder. An oil sheen was also observed on top of the leachate, indicating the foam did not carry all of the oil with it. The leachate was filtered and activated charcoal added to the solution. Very little improvement in color was observed. The pH of the leachate was increased to 11, and a subsequent increase in precipitate was observed.

Leachate With Adjustment to Acidic pH

A fresh composite leachate sample was adjusted with nitric acid to a pH of 2.5. The mixture was aerated for approximately 18 minutes and a foam sample removed. Foam bubbles were small and much drier than at a basic pH, and did not collapse as readily. Foam height decreased as the aeration continued. Surfactants were either being removed with the foam, air-stripped, or broken down in solution. Foam height stabilized as aeration continued, but the generated foam collapsed more rapidly.

After aeration, the pH of the foamate sample was between 2.5 and 3, while the leachate was between 2 and 2.5. Again, a fine black precipitate was observed at the bottom of the frothing cylinder. However, the amount of precipitate was less than that generated at a basic pH.

Activated charcoal (0.2 grams) was added to 25 ml of the acidified leachate. Much of the color was removed. A very pale yellow color remained. twenty-five ml of the foam (a yellow-gold color) was adjusted to a pH of 12. A red-brown precipitate formed, leaving a pale yellow solution.

At a pH of 2, the surfactant is likely neutral and the buffering effect of carbonate is reduced by conversion to carbon dioxide. Extended aeration of the sample should remove oil and grease in the foam, as well as convert iron +2 to iron +3, and protonate organic acids, thus decreasing their interaction with the iron.

Five-hundred ml of leachate was adjusted to a pH of 2 and aerated overnight. The solution had a final maximum turbidity reading of 7.5 NTUs (distilled water was 0.35 NTUs), and a conductivity of 14 ms/cm on the 20 ms/cm scale. The solution had a golden to yellow-brown color with a small amount of light brown precipitate at the bottom of the container. Foam from the solution also had a golden to yellow-brown color but no observable precipitate. The foamate had a pH of 2. Precipitation or dried foam was observed on the sides of the aeration vessel and on the tubing that supplied air to the diffuser.

Titration curves were developed for the pH 2 solution that was aerated overnight, and the non-pH adjusted or aerated solutions. The curve for the aerated, pH 2 leachate adjusted to a pH of 12 with the addition of sodium hydroxide is shown in Figure 2. As can be seen from the curve, buffering occurs below pH 3 and above pH 8. During titration, this solution turned from a golden to yellow-brown color at pH 2 to a brown-orange color above pH 9. A precipitate formed in this solution at a pH above 10. The titration curve for non-aerated leachate with an initial pH of approximately 7.5 is shown in Figure 3. The pH of this sample was adjusted to 12 by adding sodium hydroxide. This curve shows a buffering effect above pH 8.5. During titration, this solution turned from a gray, semi-cloudy color to golden-brown above pH 11. A precipitate formed in this solution above pH 9. The same solution adjusted to a pH of 2 by adding nitric acid shows buffering between pH 7.5 and pH 6, and below pH 2.5 (Figure 4). This solution became lighter in color below pH 5. Foam developed on top of the solution below pH 6.5. The foam did not readily collapse.

Buffering effects of the leachate are important in deciding what pH should be used in the actual aqueous leachate treatment. Adjustment of the solution pH in buffered ranges could be expensive.

<u>Leachate With Frothing Agents Added</u>

Additional froth flotation experiments were performed using sodium lauryl sulfate (SLS) and Van Waters 9N9 (VW9N9) surfactants. The following is a discussion of the procedure and observations during these qualitative studies:

<u>Sodium Lauryl Sulfate</u>. Sodium lauryl sulfate (SLS), an anionic surfactant, was added a drop at a time to three 600-ml open cells of leachate at pH 5, 7, and 9. The surfactant was prepared by adding 0.26 g SLS to a volumetric flask and adding distilled water to create a total volume of 100 mls. The SLS concentration in this sample was 9.0×10^{-3} molar (M). The pH was adjusted with concentrated sulfuric acid or sodium hydroxide and flow rates were measured with an Air Products flow meter, E29-R-150MM4.

Experiment 1: pH 5 Leachate. After the addition of sulfuric acid, the leachate turned a greenish brown color with standing foam on the surface. The height of the leachate liquid was initially 10 cm, but decreased to 9.5 cm with a flow rate of 0.54 L/min. Before SLS was added, a dry, scummy foam formed and rose up the cell, depositing scum on the cell wall. A wet foam height of 1 cm remained after three minutes, and no new foam appeared to be generated.

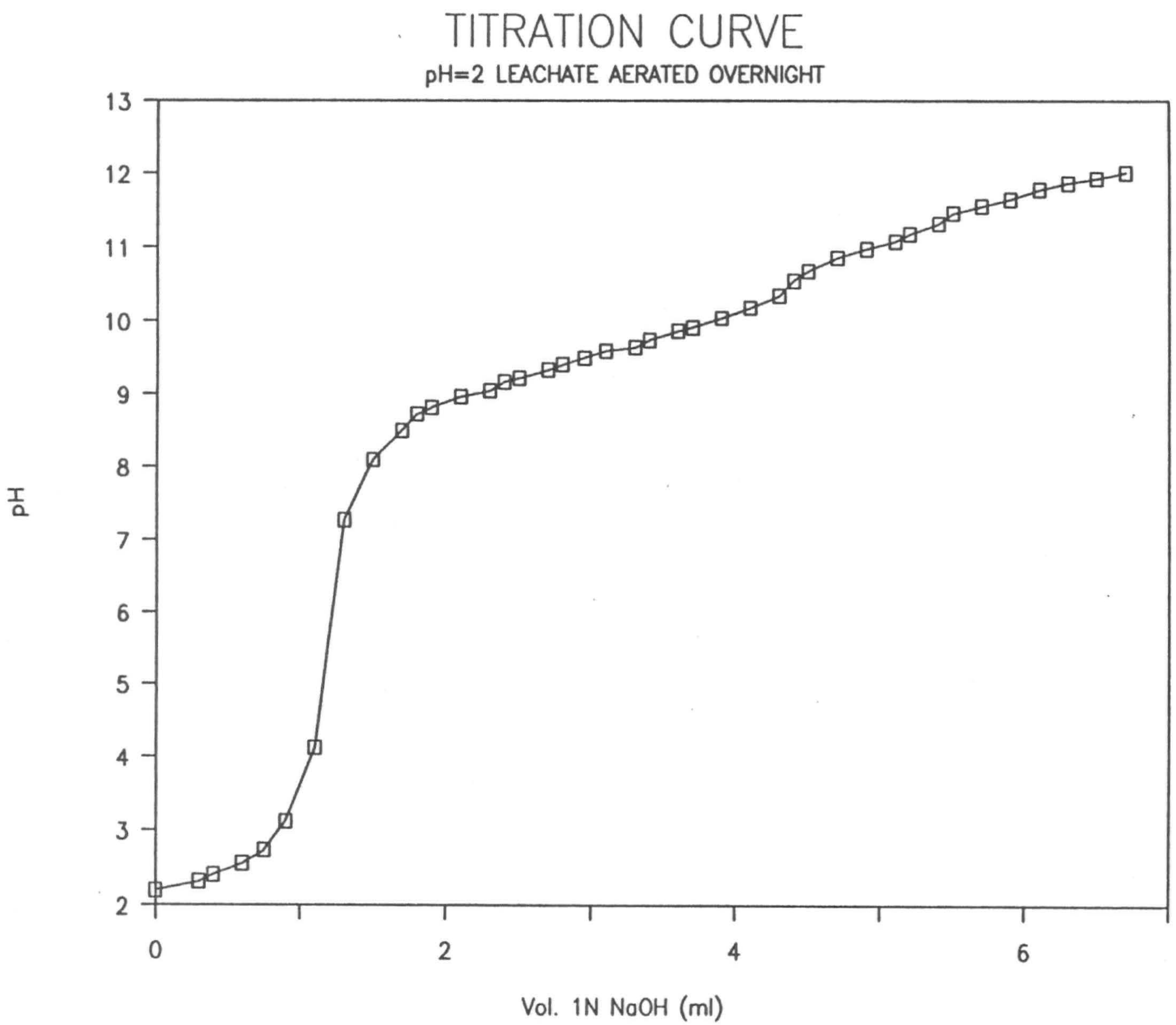


Figure 2
pH Adjustment of Aerated APL

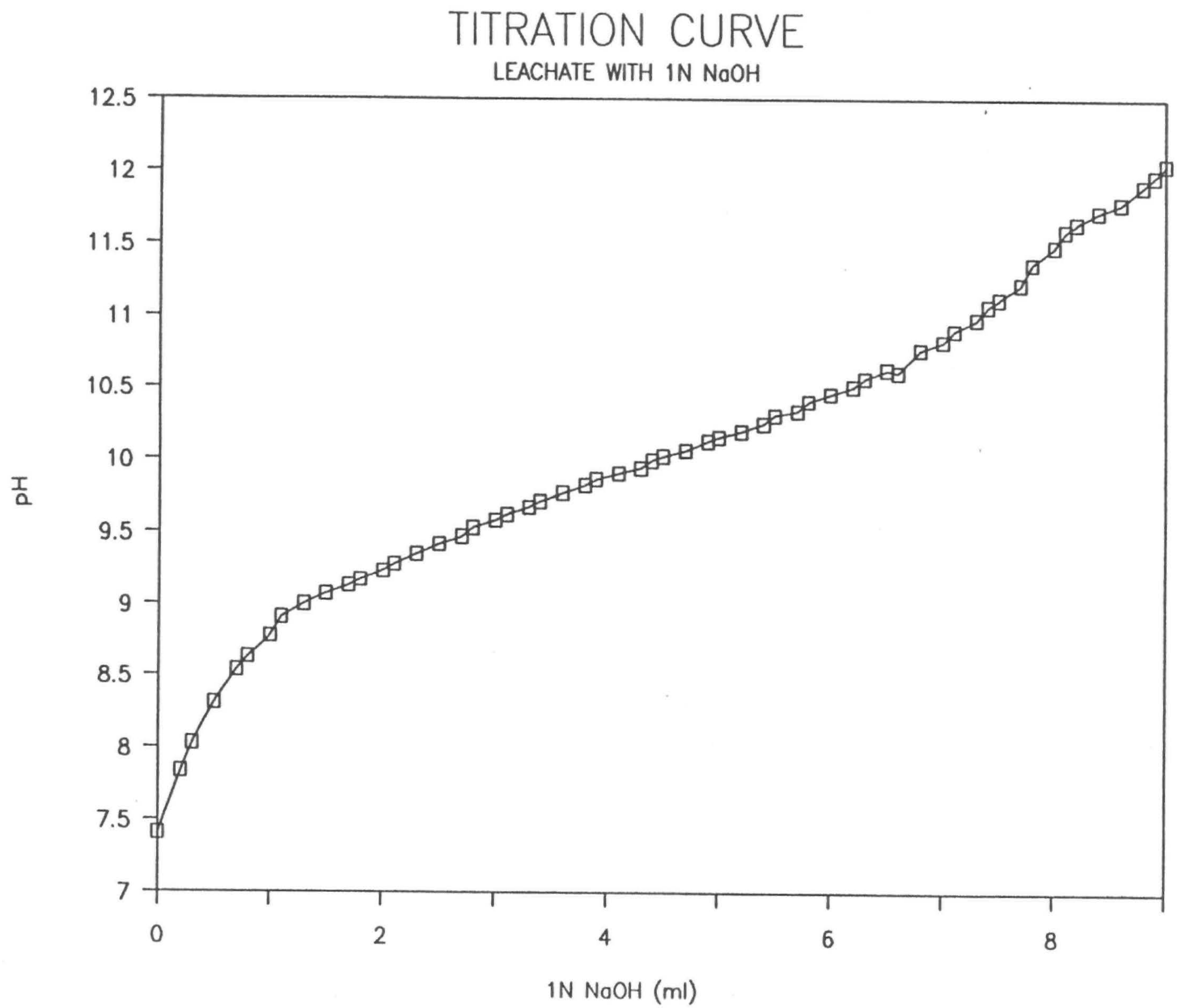


Figure 3
pH Adjustment of Non-Aerated APL

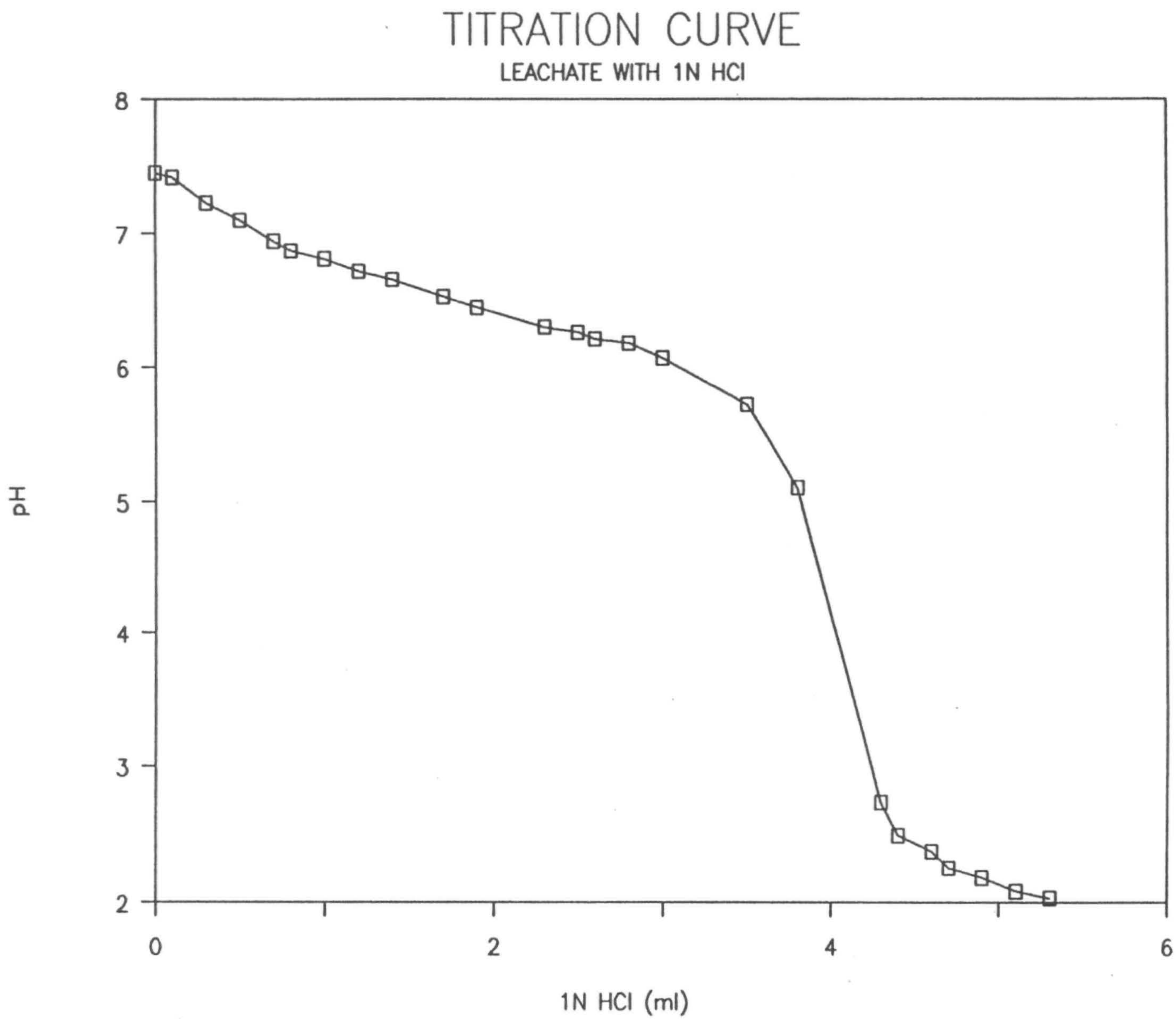


Figure 4
pH Adjustment of Non-Aerated APL

Five drops SLS were added to the cell after 10 minutes of aeration. The SLS concentration in the cell was approximately 3.8 x 10^{-6} M. At a flow rate of 1.0 L/min, the height of the liquid was 9.5 cm and the height of the wet foam was 2.5 cm. When the flow rate was increased to 3.0 L/min, the height of the liquid was 9 cm and the total foam height was 5.5 cm. When the air supply was turned off, the wet foam did not completely break down.

The air supply was started at a rate of 1.0 L/min after 5 more drops (10 total drops) of SLS were added. The SLS cell concentration was approximately 7.5 x 10^{-6} M) SLS was added. The liquid height was 9.5 cm and the wet foam height was 2.5 cm. When the flow rate was increased to 3.2 L/min, the liquid height decreased to 9 cm and the wet foam height increased to 7 cm. Very little dry foam formed. When the air supply was turned off, scum was removed from the cell walls, and approximately 1 - 2 cm of dry foam appeared on the leachate surface. A good foam-liquid interface formed.

Five more drops of SLS (15 drops total) were added to the leachate with an air flow rate of 1.0 L/min. The SLS cell concentration was approximately 1.1 x 10^{-5} M). A dry foam formed at a thickness of 2 cm, and rose toward the top of the cell. A gap formed between the dry foam and 2 cm of thick wet foam. When the flow rate was increased to 3.2 L/min, the wet foam height increased to 5 cm, while the height of the dry foam increased to 3 cm. The height of the liquid was 9 cm. At a flow rate of zero, the height of the dry foam was 2.5 cm.

Ten more drops of SLS (25 drops total) were added with a flow rate of 1.0 L/min. The SLS cell concentration was approximately 1.9 x 10^{-5} M). Dry foam, 4 cm thick, separated from the 2-cm thick wet foam. When the flowrate was increased to 3.2 L/min, a wet foam height 5 cm thick was produced, and 2 cm of additional dry foam formed. The older dry foam remained toward the top of the cell.

Twenty more drops of SLS (45 drops total) were added with an air flow rate of 1.0 L/min. The SLS cell concentration was approximately 3.4 x 10^{-5} M). The dry foam height was 5 cm and separated from the wet foam. When the flowrate was increased to 3.2 L/min, a wet foam height of 6 cm was produced. The height of the dry foam was 10 cm, and the height of the liquid was 9 cm.

Twenty more drops of SLS (65 drops total) were added to the leachate with an air flow rate of 1.0 L/min. The SLS cell concentration was approximately 4.9 x 10^{-5} M). The wet foam height was 2 cm and the dry foam height was between 8 and 10 cm.

With each addition of SLS, all dry foam appeared to be generated within 5 minutes.

Experiment 2: pH 7 Leachate. The flow meter was not used during initial foaming of the pH 7 leachate with SLS. Measurements of air pressure were taken from the regulator attached to the air cylinder.

The initial liquid height was 9.5 cm. At an air pressure of 4 lbs/sq inch (psi), the total height of liquid and foam in the cell was 18 cm. Approximately 4 cm of wet foam (reflux foam) contained dark scum on its surface, possibly oil.

Four drops of SLS were added to the leachate. The SLS concentration in the cell was approximately 3.0×10^{-6} M. Initially, the foam height dropped to 3 cm, but after two minutes, foam rose to the top of the cell. The air flow rate was decreased to 1 psi and the foam height stabilized to 3 cm. Particles were spread over the foam surface. The foam appeared more dense with the addition of SLS and reached a 5 cm thickness over time. When the air flow was stopped, the foam broke down rapidly but not completely.

Six more drops of SLS (10 drops total) were added to the leachate. The SLS cell concentration was approximately 7.5×10^{-6} M). This addition of SLS produced 10 cm of new foam, and the dry foam produced from the earlier addition rose above the new foam.

Five more drops of SLS (15 drops total) were added. The SLS cell concentration was approximately 1.1×10^{-5} M). The air flow was now adjusted to 1.9 L/min by a flow meter. The total foam height was 6 cm with a good foam-liquid boundary.

Five more drops of SLS were added (20 drops total). The SLS cell concentration was approximately 1.5×10^{-5} M. Using a flow rate of 1.9 L/min, the older foam rose to the top of the cell. A new foam, with a thickness of 6 cm, formed.

Five more drops (25 drops total) were added. The SLS cell concentration was approximately 1.9×10^{-5} M. Older foam from the top of the cell fell down on 8 cm of new foam, which appeared drier than earlier foam. Four cm of Wet foam was observed. When the air supply was turned off, the wet foam broke down rapidly, but the dry foam appeared stable. Black particles, from the top of the wet foam upward, were present on the cell wall.

Five more drops of SLS (30 drops total) were added to the leachate. The SLS cell concentration was approximately 2.3×10^{-5} M. With a flow rate of 1.9 L/min, 3 - 4 cm of wet foam formed. Overlying dry foam separated from the wet foam and rose toward the older dry foam at the top of the cell.

Ten more drops of SLS (40 drops total) were added. The SLS cell concentration was approximately 3.0×10^{-5} M. Dry foam formed and rose to the top of the cell. Wet foam remained constant at 4 cm. Over several minutes, the top of the wet foam became drier, but did not rise to the top.

Finally, 50 more drops (90 drops total) were added. The SLS cell concentration was approximately 6.8×10^{-5} M. Dry foam rose up and over the top of the cell. The effluent was cloudy and brown, and had a dark precipitate on the bottom.

Leachate at pH 7 produced foam at thicknesses greater than or equal to leachate at pH 5. However, the flow rate at pH 5 was slightly higher.

Experiment 3: pH 9 Leachate. When sodium hydroxide was added to the pH 9 leachate, a tan floc formed. The solution was brown and cloudy before aeration. No foam appeared with a flow rate of 1.0 L/min, but a slight foam appeared when the flow rate was increased to 3.3 L/min.

No foam formed until a total of 15 drops of SLS were added at a flow rate of 1.0 L/min. The SLS cell concentration was approximately 1.1 x 10^{-5} M. With a liquid height of 9.5 cm, 2 cm of wet foam slowly formed. Less than 1 cm of dry foam appeared on the wet foam surface. Less scum was evident during the pH 9 flotation experiment than during pH 5.

Three increments of five drops of SLS (20, 25, and 30 drops total) were added to the leachate. The SLS cell concentrations were approximately 1.5 x 10^{-5} M, 1.9 x 10^{-5} M, and 2.3 x 10^{-5} M, respectively. The height of the liquid remained constant at 9.5 cm. Dry foam thickness increased from 1 to 2 cm with the first addition of SLS to 4 cm with the last addition. Wet foam thickness increased from 2.5 cm to 3.5 cm with the second addition. After the last 5-drop addition of SLS, the wet foam thickness was 2 cm.

Ten more drops of SLS (40 drops total) were added to the leachate. The SLS cell concentration was approximately 3.0 x 10^{-5} M. The wet foam height was 2 cm and the dry foam height was 6 cm.

After a total of 65 drops of SLS were added, the SLS cell concentration was approximately 4.9 x 10^{-5} M. The dry foam height was 8 cm and the wet foam height was 2 cm.

Slightly less foam was generated during foaming of pH 9 leachate than pH 5 leachate using similar amounts of SLS and similar air flow rates. The foam appeared cleaner at pH 9.

Van Waters 9N9 Surfactant (VW9N9). Van Waters 9N9 (VW9N9), a nonionic surfactant, was added a drop at a time to three 600-ml open cells of leachate at pH 5, 7, and 9. A constant flow rate of 1.0 L/min was used. The surfactant was prepared by mixing a 1:10 ratio (by weight) of VW9N9 to distilled water. During the foam flotation experiments, the disk frit broke, and was replaced with a tube frit for pH 5 and 9.

Experiment 1: pH 5 Leachate. One drop of VW9N9 was added to pH 5 leachate. After one minute, the height of the liquid was 9 cm, the wet foam height was 2 cm, and the dry foam height was 1.5 cm. The dry foam contained a black oily scum distributed evenly over the surface. After three minutes, the total foam height broke down to 1 cm.

VW9N9 was added in one-drop increments up to a total of eight drops. One minute after the addition of each drop, the wet foam height remained relatively constant at 1.5 to 2 cm. The dry foam height reached up to 10 cm, but generally remained constant at 6 to 7 cm. The dry foam was composed of small bubbles at the top, and graded into larger bubbles at the wet foam interface.

Five drops of VW9N9 (13 drops total) were added. The foam was composed of larger bubbles that overflowed the cell. After the air supply was turned off, the foam remained stable.

Experiment 2: pH 7 Leachate. One drop of VW9N9 was added to the pH 7 leachate. With a flow rate of 1.0 L/min, black particles rose to the foam surface. The wet foam height was 1 cm and the dry foam height was 2 cm.

One more drop of VW9N9 (2 drops total) was added. The wet foam height was 2 cm and the dry foam height was 5 cm. These values remained constant for three minutes.

One more drop of VW9N9 (3 drops total) was added. After one minute, the wet foam height was 2 cm and the dry foam height was 8 cm. After three minutes, the wet foam dropped to 1.5 cm. The dry foam height fell to 3.5 cm due to a portion of the dry foam rising to the top of the cell.

One more drop of VW9N9 (4 drops total) was added. The height of the dry foam after one minute was 8.5 cm. After three minutes, foam overflowed the cell. The wet foam height remained constant at 1.5 cm.

Experiment 3: pH 9 Leachate. One drop of VW9N9 was added to pH 9 leachate which contained floc. A good liquid-foam interface formed. Dry foam made using VW9N9 produced smaller bubbles than dry foam using SLS. The dry foam height increased from 1.5 cm after three minutes to 2.5 cm after five minutes.

Three more drops of VW9N9 were added at 1-drop intervals. The height of the wet foam remained relatively constant at 2 cm. The dry foam increased in height from 6 cm after 2 drops of VW9N9 to 9 and 10 cm after 3 and 4 drops of VW9N9. During addition of VW9N9, particles adhered to the cell wall and appeared on the dry foam surface.

FLOCCULATION/SEDIMENTATION

Flocculation/sedimentation involves the addition of coagulating and flocculating chemicals to agglomerate suspended particles and capture certain dissolved compounds. Once the floc is formed, it may be removed by settling or flotation under quiescent conditions.

The goal of the flocculation process is to create a solid floc that settles quickly and removes PCBs and metals. The flocculation step may have the added benefit of removing semivolatile organic contaminants from the leachate.

The following is a discussion of the procedure and observations made during the qualitative flocculation/sedimentation experiments using aqueous leachate from the Midway Landfill.

Leachate With No pH Adjustment (pH Approximately 7)

Five 100-ml leachate solutions were prepared and varying doses of alum, bentonite powder, and ferric chloride added as flocculating agents. The following observations were made:

0.1 grams alum. A brown-gray floc formed and settled upon addition of the alum and mixing of the contents. Of the four alum/bentonite samples tested, this floc was the second-fastest to settle to the bottom of the container.

0.5 grams alum. Froth formed at the top of the container upon addition of alum and mixing of contents. The froth did not break down even after several hours. A white-gray floc formed and settled faster than the other alum/bentonite samples. A white-gray solution remained. Compared to the sample with 0.1 grams of alum, the clarity of the supernatants were similar. Both supernatants generated approximately 1 cm of foam when shaken vigorously. Foam in both samples collapsed rapidly. Approximately three to four times as much floc was generated in the sample containing 0.5 grams of alum than in the 0.1 gram sample.

0.1 grams bentonite powder. This solution turned dark brown upon addition of the bentonite powder. No floc appeared. A precipitate that settled to the bottom of the container appeared to be no more than the original amount of suspended solids present in the leachate before the bentonite was added.

0.5 grams bentonite powder. This solution turned medium brown upon addition and mixing of the bentonite powder. A small amount of floc may have formed, but it could have been no more than the original amount of suspended solids present in the leachate before the bentonite was added.

0.1 grams ferric chloride. A foam consisting of small bubbles was generated immediately upon addition of the ferric chloride. A scummy foam formed on the surface of the solution and adhered to the sides of the container. The foam did not collapse even after several hours. The supernatant color was a dark gray-green-brown. The pH of the solution did not change after the addition of ferric chloride. A brown floc formed after approximately two minutes, and most settled to the bottom. A small portion of the floc rose to the surface. After 25 minutes, all the floc had settled to the bottom of the container. This precipitate had a fine consistency. The supernatant had a light yellow-brown color with some precipitate still suspended. Two aliquots of the supernatant were removed and their pH adjusted. Sample 1 had the pH lowered to 5 by adding nitric acid. A golden-brown floc formed as well as a standing foam that did not readily collapse. After 25 minutes, the floc collected at the surface of the container under the foam, and a small amount settled to the bottom. Sample 2 had the pH raised to 9 by adding sodium hydroxide. Little foam was generated upon shaking of the contents. The foam collapsed rapidly. A brown floc, smaller than at pH 5, formed and settled.

Leachate With pH Adjustments

Four 90-ml leachate samples were prepared and adjusted to pH 5, 7, 9, and 10. Next, 0.1 grams of alum were added to each of these samples. The following observations were made:

pH 5. Foam formed on top of the solution immediately upon addition and mixing of the alum. The foam appeared quite dry, and did not readily collapse. A floc formed and settled to the bottom in large, solid pieces. The supernatant, a light grayish-brown color, was adjusted to a pH of 12 by adding sodium hydroxide. No color change was observed, but a fine orange-tan floc formed. After settling overnight, the supernatant was light yellow, while the floc was dark tan. The conductivity of the supernatant was 8.6 ms/cm on the 20 ms/cm scale (distilled water was 0.001 ms/cm on the 2 ms/cm scale). The supernatant was removed and aerated. A dry, scummy foam formed and continued to form after 10 minutes of aeration. The foam appeared to get drier over time. The pH of the supernatant remained at 5 after aeration.

pH 7. A good floc formed upon addition and mixing of the alum. The tan colored floc settled more quickly than at pH 5, but was easily resuspended into the solution due to its finer, light consistency. The supernatant had a gray-green color. After settling overnight, the supernatant had a brown-yellow color. The supernatant was removed and aerated. A small-bubbled, wet foam formed that rapidly collapsed when aeration was discontinued. The pH of the supernatant remained at 7 after aeration.

pH 9. A good floc formed upon addition and mixing of the alum. The tan colored floc settled more quickly than at pH 7, but again was easily resuspended into the solution. The supernatant had a light gray-brown color, and was more clear than at pH 5 or 7. After settling overnight, the supernatant had a dark brown-gold color. The supernatant was removed and aerated. A wet foam formed, somewhat drier than at pH 7, and rapidly collapsed when aeration was discontinued. The pH of the supernatant was 8 after aeration.

pH 10. A floc began to form in solution prior to adding the alum. With the alum, the tan-colored floc settled as rapidly as at pH 9, but was more solid than at pH 9. The pH of the copper-colored supernatant was adjusted to 5.5 by adding nitric acid. Upon adjustment, a scummy foam was produced that did not collapse even overnight. The clarity of the supernatant improved. After settling overnight, the supernatant had a gold color. The supernatant was removed, adjusted to a pH of 5.5, and aerated. A dry foam with a slight golden-colored scum layer on top formed, but collapsed rapidly when aeration stopped. After three to four minutes of aeration, the foam appeared to be wetter than before. After seven minutes, the foam height decreased with the same airflow rate. The original foam height could not be reached, even with excessive airflow rates.

Leachate Subject to pH Adjustments, Froth Flotation, and Flocculating Agents

Leachate, previously adjusted to a pH of 2 and aerated overnight, was readjusted to pH 7. Two 100-ml samples from the solution were prepared, and 0.1 grams of alum (Sample A) and 0.14 grams of ferrous sulfate (Sample B) were added. The following observations were made:

Sample A. A foam formed upon addition of the alum. A small amount of fine floc settled to the bottom of the container. After settling overnight, the solution was clear to light green-gray. The precipitate had a dark tan color.

Sample B. The pH dropped slightly upon addition of the ferrous sulfate, and a small amount of fine particulate matter settled to the bottom of the container. An additional 0.2 grams of ferrous sulfate was added with no visible changes observed. Sodium hydroxide was added to raise the pH to approximately 7. The solution turned a dark gray-green, and a large amount of floc formed. The solution became even darker green and more opaque as the pH was raised to 9, at which a sticky foam was observed on the sides of the container. After settling overnight, the solution had a light green to clear color. The precipitate was primarily black with a slight orange color noted on the surface. A very large amount of precipitate was observed.

CONCLUSIONS

Aeration of the APL produced significant amounts of foam. As a result, aeration in a tower would not be a desirable first step in the treatment process. Nevertheless, aeration in a tank with a large surface area may be feasible.

The Midway APL contains anionic surfactants. Aeration at neutral and basic pH generated a wet foam. Foam generated at a neutral pH did not remove an oil sheen from the surface of the leachate. Aeration of the leachate at an acidic pH generated a desirable dry foam that was sticky and scummy.

Ferric chloride and alum produced a much better floc than ferrous sulfate and bentonite. Other than producing more floc, adding higher doses of the flocculating agents did not produce any observable advantages, such as a clearer solution or better floc quality. At a basic pH, the floc formed faster but was very fine. At an acidic pH, a larger floc formed but settled slower. Also at an acidic pH, a scummy, sticky foam was generated which did not collapse even after one day.

Aeration of the aqueous leachate at neutral to acidic pH with the addition of foaming agents will be evaluated in Phase I of the treatability study. The use of ferric chloride and alum will also be evaluated further in Phase I. Ferric chloride as a flocculent could be favorable over alum since it is a strong oxidizing agent that may also decrease the chemical oxygen demand (COD) in the aqueous leachate.

Appendix C

Phase I Analysis

MIDWAY LANDFILL FEASIBILITY STUDY
TREATABILITY STUDY REPORT

PHASE I ANALYSIS

INTRODUCTION

The purpose of Phase I of the treatability study was to evaluate the efficacy of three treatment processes: (1) oil/water separation, (2) flocculation, and (3) froth flotation. Various treatment mixtures were tested for each process and qualitatively compared to find the best mixture. At specific points during Phase I, samples were collected and analyzed. These analytical results determined which treatment process could attain or surpass the Metro disposal standards. In addition, the analytical results determined which process was most effective in reducing contaminant concentrations, and if additional treatment was necessary.

FINDINGS AND OBSERVATIONS

OIL/WATER SEPARATION

Oil/water separation must be the first treatment step for the Midway landfill aqueous phase leachate (APL) because a limited amount of oil is present in the leachate and free oil may interfere with the other treatment technologies. Oil was removed from the landfill and mixed with an APL sample to simulate the mixing that may occur during pumping of the leachate.

The purpose of the oil/water separation was to (1) measure the amount of PCBs that were transferred from the oil to the APL, and (2) test the effectiveness of the oil/water separation process by measuring the level of fats, oils, and grease (FOG) that was transferred to the APL. The overall plan was to see if the levels of PCBs and FOG in the APL would be acceptable to the Des Moines sewer system without any further treatment.

First, 500 ml of oil from EW-39D was mixed with 3 L of APL. The mixture was shaken for one minute and then allowed to sit for 24 hours. After 24 hours, the mixture was shaken again for five minutes and then poured into a 1-liter separatory funnel. The three-liter oil/water mixture was separated in three 1-liter steps. The two phases were allowed to separate for approximately 30 minutes before samples were taken. The oil (top) phase was a thick, black layer. The aqueous (bottom) phase was clear with suspended solids dispersed throughout. The aqueous phase was removed first through the bottom stopcock into a sample container for PCB and FOG analysis, while the oil was poured from the top and was analyzed for PCBs.

For the first separation round, the aqueous phase was decanted off into one sample container and analyzed for PCBs. This sample was labeled TS-1 and was approximately 900 ml. The remaining oil layer was then poured into one sample container, labeled TS-2, and also analyzed for PCBs. During the second separation round, only the aqueous phase was removed, and analyzed for PCBs. This sample was labeled TS-3 and was approximately 750 ml. The remaining mixture was poured into the separatory funnel and allowed to separate. The aqueous phase was decanted off into a sample container, labeled TS-4, and analyzed for FOG. Approximately 500 ml of sample was obtained.

Laboratory analytical results indicated initial PCB levels of 900 parts-per-million (ppm) in the oil. The initial PCB concentration in the composite APL was 6 parts-per-billion (ppb) (Table 1). Analysis of the oil phase (TS-2) after the oil/water separation test showed PCB levels of 940 ppm. The difference between the PCB levels in the oil (900 ppm) versus the PCB levels in the oil phase after oil/water separation (940 ppm) are not significant due to the inherent errors in EPA Method 8080. Analysis of the aqueous phase samples indicated PCB levels of 158 ppb (TS-1) and 217 ppb (TS-3). Finally, analysis of the last aqueous phase sample (TS-4) showed a FOG concentration of 91 ppm.

Table 1. PCB and FOG analytical results of the oil/water separation tests.

	Initial Conc.		Concentration After Oil/Water Separation		
Contaminant	Oil	APL	Oil	APL	Metro Std.
PCB (ppb)	900	6	940	217	500[a]
Oil/Grease (ppm)	NA	NA	NA	91	100

[a] The Metro standard for PCBs is based on the discharge of PCB-contaminated waste from a local Treatment, Storage, and Disposal facility.

NA = Not analyzed.

FLOCCULATION/SEDIMENTATION

Flocculation/sedimentation involves adding coagulating and flocculating chemicals to a solution to agglomerate suspended particles and capture certain dissolved compounds. Once the "floc" is formed, it may be removed by settling or flotation under quiescent conditions.

Analysis of the leachate comprising the composite samples used in the treatability study is presented in Table 2. The concentration of contaminants in the composite APL will be lower than those specified in Table 2 because of dilution that occurs in preparation of the APL. The goal of the flocculation process was to create a solid floc that agglomerates quickly and removes PCBs and metals from the Midway landfill APL. The purpose of the Phase I experiments was to identify the "best" flocculent and conditions for flocculation. The best flocculent is defined as the flocculent that clears quickly with a minimum dose and produces a supernatant that is clear. The two flocculents studied were alum and ferric chloride ($FeCl_3$).

The Phase I flocculation experiments were broken down into four stages. The first stage involved testing the effect of different flocculent doses on the flocculation process. The second stage tested the effect of various pH levels on the flocculation process. The third stage tested the effect of polymers on the flocculation process. Finally, the fourth stage looked at settling rates of the floc. The "best" results or conditions from each stage of experiments were used in each successive stage.

Stage 1 - Dose Effects

These experiments tested the effects of various doses of alum and ferric chloride on the flocculation process.

Determination of Alum Dose. Five different doses of alum were added to 100 ml of leachate in 250-ml Erlenmeyer flasks. The doses were 0.1, 0.5, 1.0, 1.5, and 2.0 g. The following observations were made:

0.1 g alum. No significant change occurred in the leachate throughout the experiment.

0.5 g alum. A thick, grey floc Immediately formed throughout the solution. The floc settled to the bottom and was approximately 1.1 cm thick. The supernatant was cloudy and had a grey/white tint. A layer of white floc settled on top of the layer of grey floc. Stable foam was produced on the surface.

1.0 g alum. A thick, grey floc immediately formed throughout the solution. The floc settled to the bottom and was approximately 1.5 cm thick. The supernatant had a grey/white tint, and was clearer than the 0.5 g alum supernatant, but not as clear as the 0.1 g alum supernatant. Stable foam was produced, and was thicker than the foam for 0.5 g alum.

1.5 g alum. A chunky, grey floc immediately formed and floated to the surface. This floc was approximately 0.3 cm thick. Initially, the solution was green and cloudy. Later, some of the floc began sinking. There was more total floc (floating and sinking) here than for 2.0 g alum. The supernatant now had a whiter tint, and was clearer than the 2.0 g alum supernatant.

TABLE 2 - General Chemical Parameters in Aqueous Leachate
Midway Landfill - Kent, Washington
FS Round 4, November 1989

ANALYSIS	UNITS	WELL IDENTIFICATION LW-1	LW-2	EW-5	EW-7	EW-24	EW-40D	EW-46D	Duplicate EW-46D	EW-50D
Nitrite	mg N/l	0.032	0.008	0.007	0.006	0.029	<0.005	0.016	0.024	0.011
Nitrate	mg N/l	0.08	<0.05	0.05	<0.05	<0.05	0.10	0.10	0.10	0.06
Ammonia	mg N/l	660	370	180	140	220	650	500	430	260
Sulfide	mg/l	0.23	0.31	0.09	0.09	8.1	2.0	0.36	0.12	0.35
Sulfate	mg/l	83	83	<4000*	92	<4000*	<4000*	<4000*	<4000*	<4000*
Chloride	mg/l	4000	900	22	55	850	57	2200	2100	68
Alkalinity as CaCO3	mg/l	3200	2100	2000	1600	2000	3300	2300	2400	1500
Carbonate as CaCO3	mg/l	<5	<5	<5	<5	<5	<5	<5	<5	<5
Bicarbonate as CaCO3	mg/l	3200	2100	2000	1600	2000	3300	2300	2400	1500
Hydroxide as CaCO3	mg/l	<5	<5	<5	<5	<5	<5	<5	<5	<5
Fluoride	mg/l	0.5	<0.5	<0.5	<0.5	1.4	0.5	<0.5	<0.5	<0.5
TDS	mg/l	6700	3000	2400	2300	3600	7200	6100	5600	4100
Hardness	mg/l	590	530	810	850	850	450	680	700	610
TOX	mg/l	11	3.1	0.82	0.90	3.0	11	4.1	6.1	4.0
TOC	mg/l	510	260	170	130	330	760	460	460	250
BOD	mg/l	37	58	13	8.9	35	106	64	83	40
COD	mg/l	1900	1000	580	270	1000	2500	1700	1700	940
Cyanide	mg/l	0.3	<0.1	<0.1	<0.1	0.1	0.3	0.2	0.2	<0.1

NOTES:
* Diluted due to matrix interference.

TABLE 2 – Volatile Organic Concentrations in Aqueous Leachate
Midway Landfill – Kent, Washington
EPA Method 8240
FS Round 4, November 1989

COMPOUND	Detection Limit (ug/l)	WELL IDENTIFICATION LW-1	LW-2	EW-5	EW-7	EW-24	EW-40D	EW-46D	Duplicate EW-46D	EW-50
Benzene	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorobenzene	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	50	ND	ND	ND	ND	ND	170	ND	ND	ND
Styrene	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Xylenes	50	ND	ND	ND	ND	ND	210	ND	ND	ND
Acetone	500	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloromethane	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromoform	250	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromomethane	500	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Butanone (MEK)	500	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Disulfide	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroethane	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloromethane	500	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibromochloromethane	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethene	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
total 1,2-Dichloroethene	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloropropane	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
cis-1,3-Dichloropropene	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
trans-1,3-Dichloropropene	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Hexanone (MBK)	500	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Methyl-2-Pentanone (MIBK)	500	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	250	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachlorothene	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl Acetate	500	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl Chloride	50	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes:
High detection limit due to matrix effect.

TABLE 2 – Tentatively Identified Volatile Organic Compounds in Aqueous Leachate
Midway Landfill – Kent, Washington
EPA Method 8240
FS Round 4, November 1989

Compound	Scan Number	Estimated Concentration (mg/l)
LW-1		
None detected at >10% of nearest internal standard		
LW-2		
Hydrocarbon	1406	320
Hydrocarbon	1434	260
Hydrocarbon	1462	400
Hydrocarbon	1709	290
EW-5		
None detected at >10% of nearest internal standard		
EW-7		
None detected at >10% of nearest internal standard		
EW-24		
None detected at >10% of nearest internal standard		
EW-40D		
None detected at >10% of nearest internal standard		
EW-46D		
None detected at >10% of nearest internal standard		
EW-46D Duplicate		
None detected at >10% of nearest internal standard		
EW-50		
None detected at >10% of nearest internal standard		

TABLE 2 – Semivolatile Organics Concentrations in Aqueous Leachate
Midway Landfill – Kent, Washington
EPA Method 8270
FS Round 4, November 1989

COMPOUND	Detection Limit (ug/l)	WELL IDENTIFICATION and Dilution Factor							Duplicate	
		LW-1 (5)	LW-2 (1)	EW-5 (2)	EW-7 (1)	EW-24 (4)	EW-40D (10)	EW-46D (50)	EW-46D (50)	EW-50D (1)
ACID:										
Benzoic Acid	50	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenol	10	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Methylphenol	10	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	10	100	ND	ND	ND	ND	ND	ND	ND	ND
BASE/NEUTRAL:										
Bis(2-ethylhexyl)phthalate	10	ND	180	70	ND	ND	ND	ND	ND	34
Diethylphthalate	10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Di-n-butylphthalate	10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Di-n-octylphthalate	10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	10	ND	ND	ND	21	ND	ND	630	650	22
Acenaphtylene	10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)anthracene	10	ND	ND	ND	ND	ND	ND	380	390	ND
Anthracene	10	ND	ND	ND	ND	ND	ND	520	480	ND
Benzo(a)pyrene	10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzofuran	10	ND	ND	ND	14	ND	ND	430	400	10
Chrysene	10	ND	ND	ND	ND	ND	ND	450	460	ND
Fluoranthene	10	ND	ND	ND	ND	ND	ND	1600	1500	ND
Fluorene	10	ND	ND	ND	15	ND	ND	620	560	13
2-Methylnaphthalene	10	ND	12	ND	ND	ND	110	690	310	34
Naphthalene	10	140	63	56	86	48	300	930	840	38
N-Nitrosodiphenylamine	10	ND	23	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	10	ND	ND	25	ND	ND	ND	2000	2100	16
Pyrene	10	ND	ND	ND	ND	ND	ND	1200	1200	14

NOTE:

Only those compounds detected in samples or in leachate samples during the Remedial Investigation are listed

TABLE 2 – Tentatively Identified Semivolatile Organic Compounds in Aqueous Leachate
Midway Landfill – Kent, Washington
EPA Method 8270
FS Round 4, November 1989

Compound	Scan Number	Estimated Concentration (ug/l)
LW-1		
Total Extractable Hydrocarbons C10-C25	750 - 2500	10,000
LW-2		
Total Extractable Hydrocarbons C8-C28	500 - 2500	9,000
EW-5		
Total Extractable Hydrocarbons C11-C28	750 - 2500	7,000
EW-7		
Total Extractable Hydrocarbons C10-C28	700 - 2500	900
EW-24		
Total Extractable Hydrocarbons C9-C30+	500 - 2500	6,000
EW-40D		
Total Extractable Hydrocarbons C9-C30+	500 - 2500	30,000
EW-46D		
Total Extractable Hydrocarbons C8-C30+	500 - 2500	40,000
EW-46D Duplicate		
Total Extractable Hydrocarbons C10-C28	750 - 2500	30,000
EW-50D		
Total Extractable Hydrocarbons C8-C30	500 - 2500	5,000
Reagent Blank		
Hydrocarbon C25	2087	10

TABLE 2 – Total Metals in Aqueous Leachate
Midway Landfill
Kent, Washington
FS Round 4, November 1989

METAL	SYMBOL	DETECTION LIMIT (mg/l)	WELL IDENTIFICATION LW-1	LW-2	EW-5	EW-7	EW-24	EW-40D	EW-46D	DUPLICATE EW-46D	EW-50D
Calcium	Ca	0.05	96	97	170	220	210	82	130	130	140
Magnesium	Mg	0.01	85	70	95	76	79	60	88	91	62
Potassium	K	0.1	580	290	170	150	270	380	590	620	330
Sodium	Na	0.1	1200	550	370	210	510	950	840	880	600
Iron	Fe	0.01	3.7	16	3.6	4.1	0.49	5.1	23	16	19
Manganese	Mn	0.01	0.18	0.23	0.40	0.89	0.53	0.20	0.50	0.44	0.50
Aluminum	Al	0.2	ND	0.5	ND	ND	0.3	2.1	7.0	2.3	ND
Antimony	Sb	0.03	ND	ND	ND	ND	ND	ND	ND	0.04	ND
Arsenic	As	0.002	0.010	0.022	0.004	ND	0.004	0.019	0.023	0.018	0.005
Barium	Ba	0.01	1.0	1.0	0.70	0.62	0.54	0.80	1.0	0.92	0.90
Beryllium	Be	0.005	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	Cd	0.005	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	Cr	0.01	0.03	0.02	ND	0.02	0.04	0.04	0.03	ND	0.01
Cobalt	Co	0.01	0.03	0.02	ND	ND	0.01	0.04	0.02	0.02	0.02
Copper	Cu	0.02	0.04	0.04	ND	0.03	0.02	ND	0.06	ND	ND
Lead	Pb	0.003	0.004	0.032	0.008	ND	0.005	0.017	0.36	0.081	ND
Mercury	Hg	0.0005	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nickel	Ni	0.01	0.10	0.03	0.01	ND	0.02	0.17	0.09	0.07	0.04
Selenium	Se	0.002	ND	ND	ND	ND	ND	ND	ND	ND	ND
Silver	Ag	0.01	ND	ND	0.02	ND	ND	0.02	0.02	ND	ND
Thallium	Tl	0.002	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vanadium	V	0.01	ND	ND	ND	ND	ND	0.01	0.01	ND	ND
Zinc	Zn	0.01	0.14	0.78	0.40	0.14	0.14	0.42	0.69	0.40	0.35

TABLE 2 – Organochlorine Pesticides and PCBs in Aqueous Leachate
Midway Landfill – Kent, Washington
EPA Method 8080
FS Round 4, November 1989

	Detection Limit	WELL IDENTIFICATION								
									Duplicate	
COMPOUND	(ug/l)	LW-1	LW-2	EW-5	EW-7	EW-24	EW-40D	EW-46D	EW-46D	EW-50D
Aldrin	0.050	ND	ND	ND	ND	ND	ND	ND	ND	ND
Alpha-BHC	0.050	ND	ND	ND	ND	ND	ND	ND	ND	ND
Beta-BHC	0.050	ND	ND	ND	ND	ND	ND	ND	ND	ND
Gamma-BHC (Lindane)	0.050	ND	ND	ND	ND	0.30 J	ND	ND	ND	ND
Delta-BHC	0.050	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlordane	0.50	ND	ND	ND	ND	ND	ND	ND	ND	ND
P,P'-DDD	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
P,P'-DDE	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
P,P'-DDT	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dieldrin	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endosulfan I	0.050	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endosulfan II	0.10	0.12	ND	ND	ND	ND	ND	ND	ND	ND
Endosulfan Sulfate	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endrin	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endrin Ketone	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Heptachlor	0.050	ND	ND	ND	ND	ND	ND	ND	ND	ND
Heptachlor Epoxide	0.050	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methoxychlor	0.50	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toxaphene	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB 1016	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB 1221	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB 1232	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB 1242	1.0	ND	6.3 J	1.4	ND	ND	28*	7.7	3.8	2.3
PCB 1248	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB 1254	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB 1260	1.0	ND	ND	ND	ND	ND	3.0	ND	ND	2.1

NOTE:

J indicates estimated value
* Dilution factor of 5

2.0 g alum. A chunky, grey floc immediately formed. Some of the floc sank and some of the floc floated. The floating floc was approximately 0.1 cm thick. The supernatant had a green tint and cleared faster than the 1.5 g alum supernatant.

After allowing these solutions to sit overnight, the following observations were made:

0.5 g alum. All of the floc had settled to the bottom with a layer of white floc on top of the grey floc. The supernatant was clearer than the 1.5 g alum supernatant, and had some residual foam on top.

1.0 g alum. All of the floc had settled to the bottom of the flask. There was more floc here than in all the other mixtures. The floc was grey, thick, and stable. This supernatant was clearer than all the rest, and had no foam on the surface.

1.5 g alum. Both surface and bottom floc was observed. There was more surface and bottom floc than the 2.0 g alum solution. The floc was grey, chunky, and stable. The supernatant was clearer than the 2.0 g alum supernatant.

2.0 g alum. Only a small amount of floc had formed. Both surface and bottom floc was observed. The supernatant was cloudy and had a pale green tint.

The dose experiments with alum and no pH adjustments indicated that an alum dose of 1.0 g/100 ml produced a supernatant of greatest clarity compared to other doses. However, the alum dose of 0.5 g/100 ml had a performance that was very close and at half the dose. Therefore, the dose of 0.5 g/100 ml was carried into the pH tests.

Determination of Ferric Chloride Dose. Five different doses of ferric chloride ($FeCl_3$) were added to 100 ml of leachate in 250-ml Erlenmeyer flasks. The doses were 0.1, 0.5, 1.0, 1.5, and 2.0 g. The following observations were made:

0.1 g ferric chloride. The mixture formed a floating brown floc with a small amount of foam. The supernatant was clear and had a yellow tint.

0.5 g ferric chloride. The supernatant was dark brown and cloudy. More foam was produced than for the 0.1 g ferric chloride solution.

1.0 g ferric chloride. The supernatant was darker and had more foam than the 0.5 g ferric chloride supernatant.

1.5 g ferric chloride. The clarity of the supernatant was identical to the 1.0 g ferric chloride supernatant.

2.0 g ferric chloride. The solution was identical to the 1.5 g ferric chloride solution, but contained more foam than the other solutions.

This initial range of ferric chloride doses was to high. Therefore, four additional doses were tested by adding to 100 ml of leachate in 250-ml Erlenmeyer flasks. The doses were chosen to encompass the dose of 0.1 g. The doses were 0.01, 0.05, 0.15, and 0.20 g. The following observations were made:

0.01 g ferric chloride. The solution became cloudy and had a dark grey tint. No floc formed. No foam was generated.

0.05 g ferric chloride. The floc began to form immediately. Some settled out and some rose to the surface. The supernatant was cloudy and had a dark brown/grey tint, but was clear enough to see through. When the flask was disturbed, some of the floc on the bottom floated to the surface. The surface floc was 0.9 cm thick. The bottom floc was not measurable.

0.15 g ferric chloride. The floc formed immediately and began floating to the surface. This solution cleared faster than the other solutions. The supernatant was pale yellow and clearer than the 0.05 g ferric chloride supernatant. All the floc rose to the surface and was approximately 1.1 cm thick. Also, 0.4 to 0.7 cm of foam remained on the surface.

0.20 g ferric chloride. This solution reacted similarly to the 0.15 g ferric chloride solution. There was a slight amount of floc on the bottom. Most of the floc rose to the surface and was approximately 1.2 cm thick. The foam was the same thickness as the 0.15 g ferric chloride solution (0.4 to 0.7 cm), but was a darker brown. The supernatant was clearer than all the others, including the 0.10 g ferric chloride supernatant.

After sitting overnight, the following observations were made:

0.05 g ferric chloride. There was no floating floc. There were large, stable chunks of floc on the bottom of the flask. Gentle agitation of the flask did not break the chunks apart. The supernatant was clear and had a pale yellow tint.

0.10, 0.15, and 0.20 g ferric chloride. Most of the floc was floating. After gentle agitation of the flask, some of the floc sank. The supernatant was clear and had little or no tint.

A ferric chloride dose of 0.20 g/100 ml showed the best performance. However, other smaller doses of ferric chloride performed almost as well. A dose of 0.05 g/100 ml was carried over into the pH tests.

<u>**Stage 2 - pH Effects**</u>

The second stage of the Phase I flocculation experiments involved testing the effects of pH on flocculation using the best doses of alum and ferric chloride from the stage 1 experiments.

Effect of pH on Alum Flocculation. Five 250-ml Erlenmeyer flasks were each filled with 100 ml of leachate. Each flask was then adjusted to a specific pH by adding either sodium hydroxide (NaOH) to raise the pH or hydrochloric acid (HCl) to lower the pH. The five different pH levels were 4.5, 6, 7, 8, and 9.5. The initial pH of the leachate was 7.5.

The leachate changed noticeably after pH adjustments. The leachate at pH 4.5 was light green and cloudy. The leachate at pH 6 and 7 was dark green and cloudy. The leachate at pH 8 was dark brown and cloudy. The leachate at pH 9.5 was a clear, dark brown solution with some sediments that had settled to the bottom. Finally, 0.5 g of alum was added to each flask, and the following observations were made:

pH 4.5. The solution became brown and cloudy. No floc formed and no foam accumulated.

pH 6. The solution became dark brown and cloudy. No floc formed, but a layer of foam was produced.

pH 7. The solution became grey and cloudy. A floc formed instantly and began to sink. A layer of foam formed on the surface.

pH 8. The solution became grey and cloudy. A floc formed instantly and began to sink. The floc settled faster than at pH 7 or pH 9.5. A layer of foam formed on the surface and was thicker than the foam at pH 7. The solution was clearer than all the others.

pH 9.5. The solution became dark grey and cloudy. A floc formed instantly, but remained dispersed throughout the solution. The floc did not settle to the bottom or float to the surface. The floc was very thick and distributed throughout the solution. A layer of foam formed on the surface and was approximately the same thickness as the foam at pH 8.

Effect of pH on Ferric Chloride Precipitation. Five 250-ml Erlenmeyer flasks were each filled with 100 ml of leachate. Each flask was then adjusted to a specific pH using either sodium hydroxide to raise the pH or hydrochloric acid to lower the pH. The five different pH levels were 4.5, 6, 7, 8, and 9.5. The initial pH of the leachate was 7.5. Finally, 0.05 g of ferric chloride was added to each flask and the following observations were made:

pH 4.5. A white standing foam formed and the solution became orange/brown and cloudy. After an extended period, the solution turned yellow/orange and clear. The color of the solution was lighter than all the others. There was a small amount of surface and bottom floc.

pH 6. A white standing foam was formed, and the solution became dark brown and cloudy. After a while, the solution became dark orange and clear. There was some surface and bottom floc.

pH 7. A brown standing foam formed and the solution became dark brown and cloudy. After an extended period of time, the solution did not change, and there was no apparent floc formation.

pH 8. A brown standing foam, darker than at pH 7 formed, and the solution became dark brown and cloudy. After an extended period of time, there was little change in the solution and no apparent floc formation.

pH 9.5. Initially, an even darker brown standing foam formed. There was a noticeable floc formation throughout the solution. After a while, the solution became the same color as the pH 7 and 8 solutions, but clear. At this time, there was no apparent floc formation. However, there were some sediments on the bottom of the flask.

Adjusting the pH did not significantly effect ferric chloride performance. This dose of ferric chloride (0.5 g/100 ml) was probably too small. A dose of 0.1 g/100 ml was used in all the remaining experiments. This larger dose cleared faster and also produced a clearer supernatant than the smaller dose. The best dose of ferric chloride produced a more compact floc than the best dose of alum (at any pH). Alum typically produces a light, fluffy floc. As a result, alum was dropped from further testing.

Stage 3 - Polymer Effects

The third stage of the Phase I experiments tested the effect of polymers on the flocculation process using the best dose of ferric chloride from the first stage of experiments.

Effect of Polymers on Ferric Chloride Flocculation. Five 250-ml Erlenmeyer flasks were each filled with 100 ml of composite APL. Next, 0.1 g of ferric chloride was added to each flask. Finally, 0.5 ml of a 0.1 percent solution of a different polymer was added to four of the flasks. No polymer was added to the fifth flask. The concentration of the polymer in the leachate solution was 5 ppm. The pH of the leachate was 7.5 before addition of reagents. After addition of the ferric chloride, the pH decreased to 7.0. Polymers from two different companies were used. The first set of tests used Nalco Polymers. The second set of tests used Betz Polymers. These polymers were recommended by the manufacturers based on their review of the properties of the Midway APL.

Nalco Polymers. The first four polymers were anionic polymers from the Nalco Corporation. The code numbers for these polymers were 672, 673, 674, and 675.

The addition of the polymers appeared to help the solution clear faster. The clarity of the liquid phase from darkest to lightest (clearest) was as follows: (1) 675, (2) 673, (3) 672, (4) 674, and (5) no polymer. The amount of floating floc from smallest to largest was as follows: (1) 675, (2) 673, (3) 672, (4) 674, and (5) no polymer. There was no floc on the bottom of any of the flasks.

The above experiment was run again without polymer 674. The clearing rates from slowest to fastest were: (1) 675, (2) no polymer, (3) 672, and (4) 673. The clearing rates for polymers 672 and 673 were very close. 672 and the no polymer solution had equally clear liquid phases. 673 was slightly darker than 672, and had a yellow tint. There were equal amounts of floating floc in all flasks. The no polymer solution, 672, and 673 had equal amounts of floc on the bottom, while 675 had the greatest amount.

Betz Polymers. The next three polymers were from Betz Industrial and were anionic polymers. The code numbers for these polymers were 1115L, 1125L, and 1131L. The fourth polymer was Nalco polymer 672, which was carried over from the first tests.

The mixture for polymers 1115L and 1125L cleared rapidly. The liquid phase had a yellow tint and all the floc floated to the surface. The mixture for polymer 672 did not clear as fast, and most of its floc floated to the surface. The mixture for polymer 1131L cleared even slower than 672, and most of its floc sank to the bottom of the flask.

The two Betz polymers 1115L and 1125L performed better than all the rest, including the Nalco polymers. Betz polymer 1115L was carried into the next round of experiments.

<u>Effect of pH on Flocculation with Ferric Chloride and Polymer 1115L</u>. Two 250-ml Erlenmeyer flasks were each filled with 100 ml of leachate. Next, 0.1 g of ferric chloride was added to each flask. In one of the flasks, the pH was adjusted to 5 while the other flask was left at pH 7. Finally, 0.5 ml of polymer 1115L was added to each flask. The pH 5 mixture did not clear as fast as the pH 7 solution and the floc was less compact. Most of the floc sank to the bottom of the flask for the pH 5 mixture.

<u>Stage 4 - Clearing/Settling Rates</u>

The fourth and final stage of the Phase I experiments compared the settling rates, or clearing rates, of the untreated APL and treated APL at three different pH levels. Settling rates are needed to help size the solids removal equipment. Each mixture (batch) used 1,000 ml of APL. In order to more accurately evaluate the differences, samples were removed from the three treated APL batches and analyzed for the purgeable aromatics benzene, ethylbenzene, toluene, and xylenes (BETX), chlorinated organics, and selected metals (iron, lead, and manganese).

For the first test, settling rates of solids from untreated APL were compared with settling rates of treated APL. For the treated sample, 1.0 g of ferric chloride was added to 1,000 ml of leachate in an Erlenmeyer flask. The pH of this mixture was then adjusted to pH 5 using concentrated nitric acid. Next, 5 ml of Betz Industrial polymer 1115L was mixed into the solution. The whole mixture was then poured into a 1,000-ml graduated cylinder. In addition, 1,000 ml of untreated leachate was poured into another 1,000-ml cylinder for comparison to the treated APL. The settling rates of the two mixtures were measured using the interface height (in ml on the graduated cylinder). The interface height was measured every minute for the first 25, minutes and then every five minutes for the next 45 minutes.

The results of the settling tests are shown graphically in Figure 1. The x-axis is the amount of time, in minutes, from transfer of the mixture from the Erlenmeyer flask to the graduated cylinder. The y-axis is the height of the interface in ml. There was no observable settling of the untreated leachate, therefore, no settling curve is shown. According to the results, no significant settling of the floc occurred beyond 60 minutes.

The second test involved qualitatively comparing the clearing rates (settling rates for floc that sinks) of the pH 5 mixture with pH 7 and pH 9 mixtures. For the pH 7 mixture, 1,000 ml of leachate (initial pH = 7.5) was added to an Erlenmeyer flask. Next, 1.0 g of ferric chloride was stirred into the leachate, lowering the pH to 7. Finally, 5 ml of Betz polymer 1115L was stirred into the solution. The whole mix was then transferred to 1,000-ml graduated cylinder. The same steps were used to produce the pH 9 mixture, except that after the addition of the ferric chloride, sodium hydroxide was added to raise the pH.

There were no timed measurements taken during these settling tests. The pH 7 mixture forms a floc that floats which would make measuring "settling rates" impossible. The settling rate of the pH 9 mixture was visibly slower than the settling rate of the pH 5 and the pH 7 mixtures. In addition, the final appearance of the supernatant was much darker than the pH 5 mixture. Samples were taken of the supernatant of all three leachate mixtures. Sample 1 is the pH 9 supernatant, sample 2 is the pH 5 supernatant, and sample 3 is the pH 7 supernatant. Each solution was analyzed for BETX, chlorinated organics, and selected metals. The results of all the analyses are summarized in Table 3.

FROTH FLOTATION

Froth flotation is a method of removing fine particulates, surfactants, oils, and dissolved chemicals from water by sorbing the materials onto a foam or froth that rises to the surface of a tank or column of water. The foam is formed by vigorous aeration of the liquid from the base of the tank. The resulting foam is skimmed from the surface of the tank and treated separately.

Composite APL from Midway with various artificial foaming agents were evaluated under froth flotation process conditions. By selecting among cationic, anionic, and neutral foaming agents, it may be possible to control which chemicals are removed from the Midway APL and the amount of liquid in the foam. The goal of the experiments was to create a neutral foam that removed oils, PCBs, and colloidal metal oxides and hydroxides. The aeration step may have the added benefit of removing a large percentage of the volatile organic contaminants (VOCs) and surfactants present in the APL.

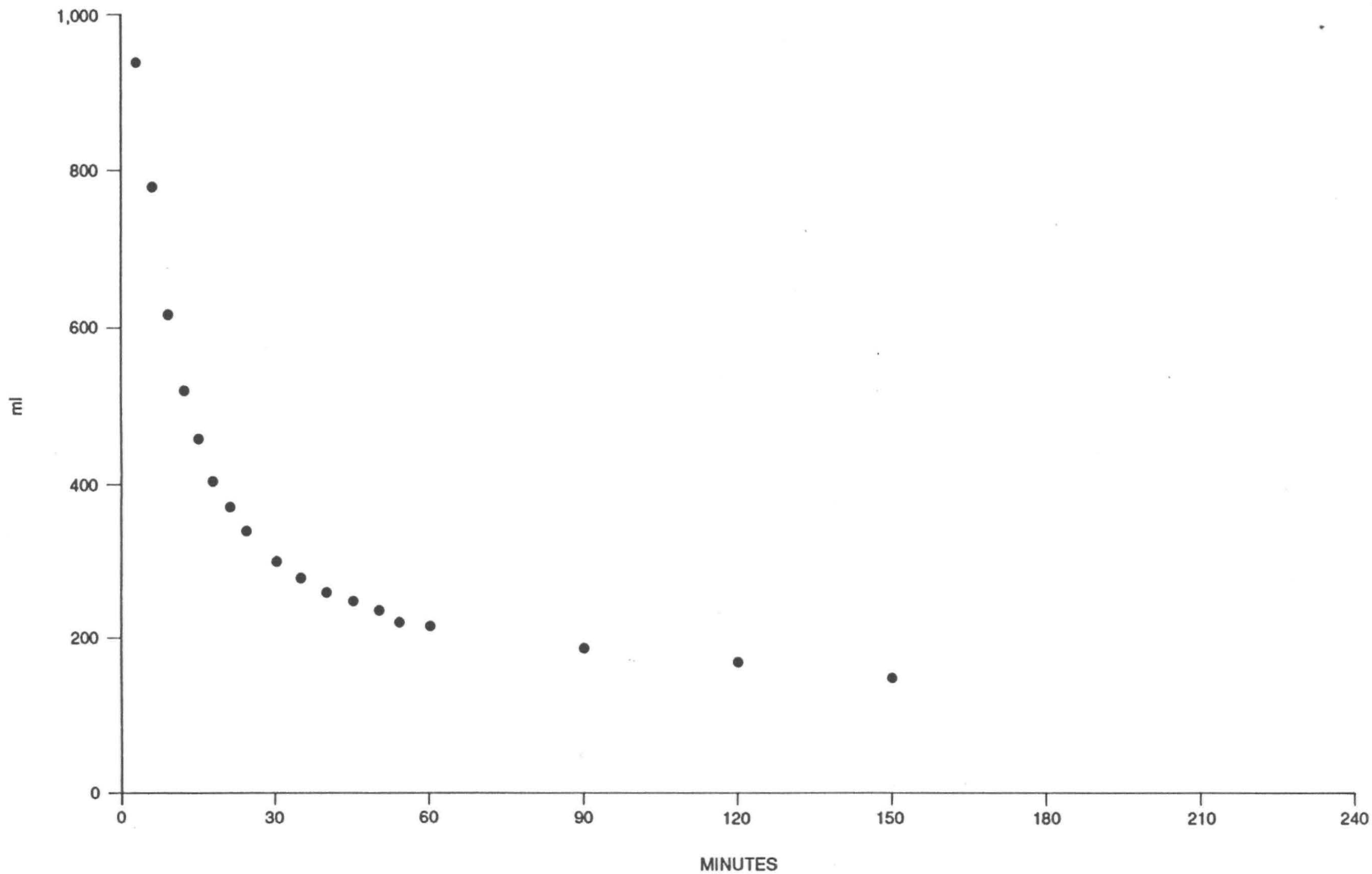


Figure 1.
Settling Rate of PH5 Leachate

Table 3. Analytical results of the flocculation experiment at pH 5, pH 7, and pH 9.

Contaminant	Maximum Initial Concentration (ppb)[a]	Max. Conc. After Flocculation (ppb) pH 5	pH 7	pH 9
Benzene	ND(50)	5	3	ND(1)
Ethyl Benzene	170	5	ND(1)	ND(1)
Toluene	ND(50)	4	3	ND(1)
Xylene	210	13	7	ND(1)
Chlor. Organics	ND(50-500)	ND(5-80)	ND(5-80)	ND(5-80)
Iron	23,000	8,200	4,800	7,800
Manganese	890	2,100 J	1,600 J	2,100 J
Lead	360	8	16	10

[a] Maximum initial concentrations were taken from the previous analytical data of samples from the eight Midway Landfill wells which comprised the composite APL used in the treatability study (see Table 2).

ND(X) = Not detected at the specified detection limit (X).

J = Estimated concentrations due to matrix interference.

The following froth flotation experiments were performed:

- Leachate at pH 5 with no surfactant (L5 - N5).
- Leachate at pH 7 with sodium lauryl sulfate (L7 - SLS).
- Leachate at pH 5 with sodium lauryl sulfate (L5 - SLS).
- Leachate at pH 7 with Van Waters 9N9 (L7 - VW9N9).
- Leachate at pH 5 with Van Waters 9N9 (L5 - VW9N9).

BETX concentrations in the original leachate samples used to prepare the composite leachate for the treatability study are summarized in Table 4. The samples of the effluent from the these experiments were analyzed for purgeable aromatics. The results of the BETX analysis of the effluent samples are summarized in Table 5. Throughout the quantitative portion of Phase I, the flow rate remained at 2.2 L/min, the leachate was aerated for one hour and the surfactant was added as needed. Effluent samples were collected in preserved 40-ml volatile organic analysis (VOA) vials and 500-ml amber glass bottles and refrigerated.

pH 5 Leachate With No Surfactant (L5-NS)

A total of 1,500 ml of leachate was adjusted to pH 5 with 85 drops of concentrated sulfuric acid (H_2SO_4). The flow rate may have been too high for the volume of leachate used. Wet foam appeared to have overflowed into the foam collector. Most of the foam was removed after 10 minutes. After aeration, the effluent (L5-NS) was left to settle overnight and then collected in a hydrochloric acid (HCl) preserved 40-ml VOA vial for BETX analysis. A sample of the foamate (F5-NS) was collected in a 500-ml amber glass bottle and refrigerated for possible future analysis.

pH 7 Leachate With Sodium Lauryl Sulfate (L7-SLS)

A total of 1,000 ml of leachate was added to the froth flotation cell. sodium lauryl sulfate (SLS) was added in 25-drop increments for a total of 825 drops. Approximately 41 ml of 9×10^{-3} M SLS was added. The cell walls were clean but particles collected on the inside cell lid. Particles were also present in the foamate. Samples were preserved using the same method described above.

pH 5 Leachate With Sodium Lauryl Sulfate (L5-SLS)

Fifty drops H_2SO_4 were added to 1,250 ml leachate to achieve pH 5. No surfactant was needed for the first two minutes of aeration. After 15 minutes, the wet foam became dry and stable and did not easily break down into foamate. After one hour, the foam became wet. Approximately 38 ml of SLS were added at a rate of approximately 760 drops per hour. The effluent sample, L5-SLS, contained a small amount of grayish-green precipitate. A trip blank, TB-1, which remained open in the lab for one day, was submitted for BETX analysis. Foamate sample F5-SLS and the remaining effluent sample L5-SLS were stored in a refrigerator.

Table 4. BETX concentrations in the original leachate samples.

Sample	BETX Concentration (ppb)
LW-1	ND(50)
LW-2	ND(50)
EW-5	ND(50)
EW-7	ND(50)
EW-24	ND(50)
EW-40D	210 (xylenes) 170 (ethylbenzene)
EW-46D	ND(50)
EW-50D	ND(50)

ND(50) = Not detected at the specified detection limit (50).

Table 5. BETX concentrations (ppb) in the effluent of the froth flotation experiments.

Sample	Benzene	Ethylbenzene	Toluene	Xylenes
L5-NS	ND(1)	ND(1)	ND(1)	1
L5-NS (Dup)	ND(1)	ND(1)	1	1
L5-SLS	ND(1)	ND(1)	1	ND(1)
L5-VW9N9	ND(1)	ND(1)	ND(1)	4
L7-SLS	ND(1)	ND(1)	2	1
L7-SLS (Dup)	ND(1)	ND(1)	2	2
L7-VW9N9	ND(1)	ND(1)	2[a]	1

[a] Toluene was found in the reagent blank for this sample.

ND(1) = Not detected at the specified detection limit (1).

pH 7 Leachate With Van Water 9N9 (L7-VW9N9)

Approximately 1,250 ml of leachate was added to the flotation cell. The initial foam height was 5.5 cm before VW9N9 was added. After the addition of VW9N9, the foam appeared wet with large bubbles. The surfactant was added at a rate of approximately 130 drops per hour in 5-drop increments. The foamate volume was approximately 600 ml and contained residual particulates. Samples collected were L7-VW9N9 and F7-VW9N9.

pH 5 Leachate With Van Water 9N9 (L5-VW9N9)

A total of 1,250 ml of leachate was adjusted to pH 5 with 70 drops of concentrated H_2SO_4. During the first five minutes of aeration, a wet foam formed and surfactant was not needed. Afterwards, VW9N9 was added in 5-drop increments for a total of 95 drops (approximately 4.8 ml) in one hour. The bubbles in the foam appeared larger with the addition of VW9N9. Samples collected were L5-VW9N9 and F5-VW9N9 (foamate).

CONCLUSIONS

With the exception of finding a nonaqueous phase to the leachate (NAPL), the analytical results of the APL samples taken when the treatability samples were collected provide no changes since the Midway remedial investigation was performed. The analytical results do indicate, however, that the concentration of PCBs in the APL are lower than expected.

Analytical results from the oil/water separation experiment indicate that both phases can be easily separated. The results also indicate that PCBs are transferred to the aqueous phase when oil is present. The PCB and oil and grease concentrations in the aqueous leachate after separation could meet Metro discharge standards without further processing.

The flocculation/sedimentation tests have identified a viable flocculent (ferric chloride) and polymer (Betz 1115L) for treatment of the Midway leachate. Ferric chloride produces a much more dense and solid precipitate than that formed with alum. Betz polymer 1115L produces a floc that settles quickly and leaves a clearer supernatant. No significant settling of the floc occurred beyond 60 minutes.

Analytical results indicated that there was no significant correlation between the pH of the solution and the efficiency of the flocculation/sedimentation process for removing metals from the APL. Lead and iron concentrations were reduced in all cases, while the apparent manganese concentration actually increased. This was probably due to matrix interferences because of the high dissolved solids content of the samples. The concentrations of manganese after treatment were therefore "flagged" with a "J" to indicate estimated values. No chlorinated compounds were detected in solution before or after flocculation. All detectable BETX concentrations were below the Metro discharge standards. Overall, flocculation improved the clarity of the solution at all pH levels.

Aeration of the APL through froth flotation reduced the concentration of VOCs in the sample. However, because the detected concentration of PCBs in the APL are low, froth flotation should not be considered a viable treatment technology for the Midway leachate.

Phase II of the Midway Landfill aqueous leachate treatability study is not necessary and will not be performed. The Phase I experiments have provided sufficient analytical results to conclude that no further processing would be required to satisfy or surpass Metro waste pretreatment standards. To discharge the treated APL to an alternative stream such as McSorley Creek (formerly Smith Creek), it is probable that drinking water or surface water standards would have to be achieved. Although it may be possible to attain or surpass these standards through further treatment of the APL (Phase II), institutional considerations would likely restrict the discharge of treated leachate to the creek.

Based on the technologies tested and evaluated during the studies, the most applicable process train for treatment of the Midway APL before discharge to Des Moines appears to be oil/water separation in combination with flocculation/sedimentation. This train will run in triplicate in Phase III of the study, and samples will be taken along each step. Composite APL used in the Qualitative and Phase I studies will be used. No pH adjustment of the APL will be made.

Appendix D

Phase III Analysis

MIDWAY LANDFILL FEASIBILITY STUDY
TREATABILITY STUDY REPORT

PHASE III ANALYSIS

INTRODUCTION

The purpose of Phase III of the treatability study was to combine the oil/water separation and flocculation/sedimentation technologies into a workable treatment process. Mixtures of composite APL and PCB-contaminated oil from Well EW-39D were run through the process in triplicate. Samples were then taken to evaluate the variability of the effluent quality and to verify that Metro pretreatment standards could be surpassed.

The final treatment process evaluated in Phase III will be conceptually designed and costed in the treatability study report. This treatment process will be considered the most applicable for treating the APL at the Midway Landfill throughout the associated feasibility study.

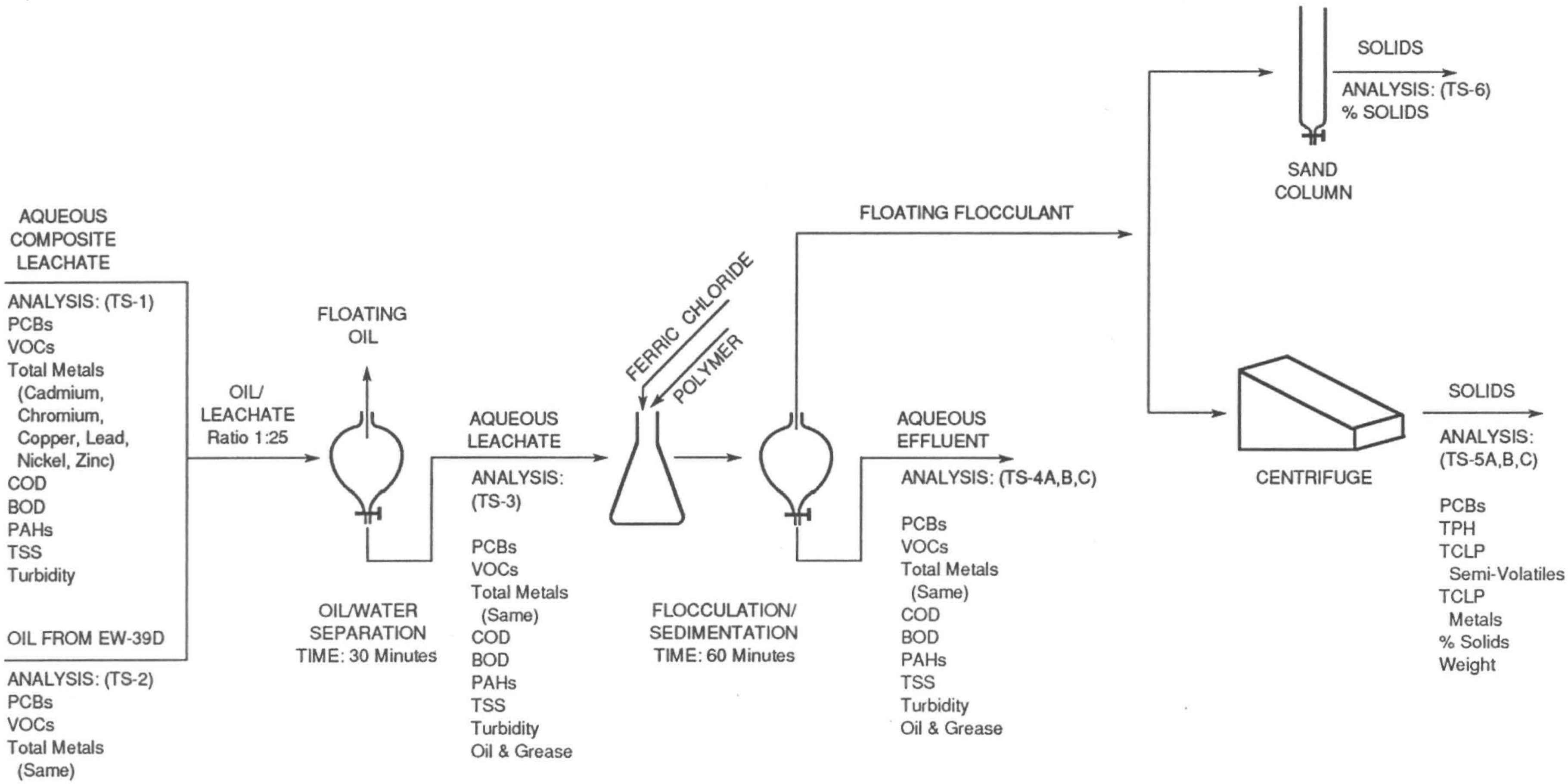
PROCEDURE

Based on analytical results from Phase I of the treatability study, the following processing parameters were used in the treatment of the APL in Phase III:

- Untreated composite APL samples were submitted to the laboratory for analysis before the Phase III process began. These analyses would provide the initial concentrations of contaminants in the composite APL to which results from the treatment processes could be compared. These samples were identified as TS-1 (Figure 1).

- Samples of the oil from Well EW-39D, identified as TS-2, were submitted to the laboratory for analysis. These analyses could indicate the source of higher contaminant concentrations found in the APL.

- The process was run with no pH adjustment of the composite APL.



Parametrix, Inc.

PCB	Polychlorinated Biphenyls
VOC	Volatile Organic Compounds
COD	Chemical Oxygen Demand
BOD	Biochemical Oxygen Demand
PAH	Polycyclic Aromatic Hydrocarbons
TSS	Total Suspended Solids
TPH	Total Petroleum Hydrocarbon
TCLP	Toxicity Characteristic Leaching Procedure

Figure 1.
Phase III
Flowchart and Analyses

- To simulate the mixing of oil and APL that may occur during extraction of the APL, PCB-contaminated oil from Well EW-39D was mixed with the composite APL in approximately a 1:25 ratio. Oil was added to the APL the night before the process run, shaken for 5 minutes, and allowed to reach room temperature overnight. The oil/APL mixtures were shaken for approximately 5 minutes before being run through any stage of the Phase III treatment process.

- Ferric chloride was used as the flocculating agent at a dose of 0.1 grams per 100 ml of APL.

- Betz polymer 1115L was used as the coagulating agent at a dose of 0.5 ml of 0.1 % polymer solution per 100 ml of composite APL (5 ppm).

Phase III of the treatability study was divided into two stages. Stage 1 involved oil/water separation with samples taken and submitted to the laboratory for analysis. Stage 2 involved oil/water separation in combination with flocculation/sedimentation. This stage was run in triplicate, and samples were taken after the flocculation/sedimentation process. Stage 2 also involved dewatering the sludge generated from the flocculation/sedimentation process.

Because of the limited volumetric capacity of the laboratory equipment used in Phase III and the sample volumes required by the laboratory for analyses, each stage of the Phase III process was divided into multiple runs.

FINDINGS AND OBSERVATIONS

STAGE 1: OIL/WATER SEPARATION

The oil/water separation process was divided into two separate runs. Run 1 consisted of 150 ml of oil mixed with 3 L of APL. Run 2 consisted of 100 ml of oil in 2 L of APL. Both runs used mixtures of composite APL from Midway and oil from Well EW-39D. Samples were taken during both runs, combined, and analyzed for volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), PCBs, metals (cadmium, chromium, copper, lead, nickel, and zinc), fats, oils, and grease (FOG), chemical oxygen demand (COD), and biological oxygen demand (BOD). First, the sample containers were filled half-way with the aqueous phase from run 1. The aqueous phase from run 2 was then added to the aqueous phase in the sample containers from run 1, and then submitted to the lab. The following observations were made:

Run 1

The 3 L of APL and 150 ml of oil were divided equally into two 2-liter separatory funnels. The mixtures were both dark brown. Foam, generated from the mixing of the oil with the APL, was present at the top of each container and remained for the 30 minutes of oil/water separation. Phase separation was noticeable after 15 minutes. After 30 minutes, the APL was dispensed from the separatory funnels into laboratory sample bottles.

As the APL was removed, a distinct line between the two phases was noted in the separatory funnels. This distinct line was not noticeable before this time, possibly due to the dark color of the mixtures. A total of approximately 180 ml of oil/emulsion was removed from the containers after the phases were separated.

Run 2

The 2 L of APL and 100 ml of oil were divided equally into two 2-liter separatory funnels. The same observations were noted as in Run 1. The APL removed from the bottom of the separatory funnels was combined with APL from Run 1 and submitted to the laboratory for analysis. These samples were identified as TS-3. Approximately 110 ml of oil/emulsion were removed from the containers after the phases were separated.

STAGE 2: OIL/WATER SEPARATION FOLLOWED BY FLOCCULATION-/SEDIMENTATION

This phase of the Phase III treatment process was run in triplicate to evaluate the variability of the effluent quality. Runs 1 and 2 were split into two runs designated 1A, 1B, 2A, and 2B. Run 3 was only run once due to insufficient sample volume. Samples of the treated effluent and the precipitate were taken after the flocculation/sedimentation process during each of the runs. The effluent samples were analyzed for VOCs, PAHs, PCBs, metals (cadmium, chromium, copper, lead, nickel, and zinc), FOG, COD, and BOD. The precipitate samples were analyzed for base, neutral, acid compounds (BNAs), PCBs, total petroleum hydrocarbons (TPH), percent moisture, and Toxic Contaminant Leaching Procedure (TCLP) metals (barium and chromium). All three runs used composite APL from Midway mixed with oil from Well EW-39D. The following observations were made:

Run 1

Run 1A. Run 1A consisted of 3 L of composite APL mixed with 120 ml of oil. The contents were added to two 2-liter separatory funnels, where the phases were allowed to separate for 30 minutes. Three liters of APL were removed from the funnels and divided equally into two 2-liter Erlenmeyer flasks. The APL was a medium gray color.

Next, 1.5 g of ferric chloride were added to each of the 1,500-milliliter volumes of APL in the two Erlenmeyer flasks and swirled for 2 - 3 minutes. A foam immediately formed on top of each solution. A precipitate also formed and remained suspended in the solution. The pH of each solution was approximately 7.

In the next step, 7.5 ml of Betz polymer 1115L (1,000 ppm) were added to each of the two flasks, giving a final polymer concentration of 5 ppm. The mixtures were swirled for several minutes. Equal amounts were poured into three Ihmhoff cones. The size of the precipitate floc immediately increased upon addition of the polymer and rose to the surface of the cones. The solutions cleared within 1 - 2 minutes, although they were allowed to separate for 1 hour. There were approximately 100 ml of precipitate at the top of each of the three cones. Approximately 5-10 ml of precipitate sank to the bottom of each cone.

After the floc cleared, no changes in the phase separation were noted. The aqueous phase was a light yellow color. The aqueous phase, along with small amounts of the precipitate, was removed from the bottom of the cones and placed into laboratory sample bottles. These samples were submitted to the laboratory for analysis after more effluent was obtained from Run 1B.

Approximately 100 ml of wet sludge from one of the Ihmhoff cones were added to a sand column for dewatering. The dried sludge was removed from the column after approximately 3 hours and submitted to the laboratory for "percent moisture" analysis. This sample was identified as TS-6.

Because the sand in the column was too dense to allow water to filter through in a relatively short period of time, a centrifuge was used to dewater the remaining sludge samples from the Phase III process.

Wet sludge (315 ml) was removed from the remaining mixtures in the Ihmhoff cones and placed into two centrifuge bottles. A foam was noted at the top of each surface of wet sludge. These mixtures were dewatered after more wet sludge was obtained from Run 1B.

Run 1B. One-liter separatory funnels were now be used for the remaining Phase III runs rather than the Ihmhoff cones. The separatory funnels provided easier sampling of the aqueous liquid and the floating precipitate.

Run 1B consisted of 3 L of APL mixed with 120 ml of oil. The observations were identical to Run 1A. The solutions cleared rapidly, although they were allowed to sit for 1 hour. The aqueous liquid was removed from the separatory funnels after the flocculation process and combined with samples from Run 1A. These samples, identified as TS-4A, were submitted to the laboratory for analysis.

An additional 235 ml of wet sludge were added to the centrifuge bottles from Run 1A for a total of 550 ml. Again, foam was noted at the surface of each container before centrifuging. The samples were dewatered in a centrifuge for 10 minutes at 1,000 rpm. The centrifuge dewatering results are summarized in Table 1.

Table 1. Centrifuge dewatering results of solids from Run 1.

Container	Wet Sludge Volume Before Centrifuging (ml)	Volume After Centrifuging	
		Solids (ml)	Liquid (ml)
1	200	50	135
2	200	55	140
3	150	25	125

The solids were removed from the centrifuge bottles and submitted to the laboratory for analysis. These samples were identified as TS-5A.

Run 2

Run 2A. Run 2A consisted of 3 L of composite APL mixed with 120 ml of oil. The mixture was added to two 2-liter separatory funnels, where the phases were allowed to separate for 30 minutes. Three liters of APL were removed from the funnels and divided equally into two 2-liter Erlenmeyer flasks. The APL was a medium gray color.

Next, 1.5 g of ferric chloride were added to each of the 1,500-milliliter volumes of APL in the two Erlenmeyer flasks and swirled for 2 - 3 minutes. A foam immediately formed on top of each solution. A precipitate also formed and remained suspended in the solution. The pH of each solution was approximately 7.

Subsequently, 7.5 ml of Betz polymer 1115L (1,000 ppm) were added to each of the two flasks, giving a final polymer concentration of 5 ppm. The mixtures were swirled for several minutes. Equal amounts were poured into three 2-liter separatory funnels. The size of the precipitate particles immediately increased upon addition of the polymer and rose to the surface of the separatory funnels.

Aqueous liquid was removed from the separatory funnels after flocculation and placed into laboratory sample bottles. These samples were submitted to the laboratory for analysis after more liquid was obtained from Run 2B.

Run 2B. Run 2B consisted of 3 L of APL mixed with 120 ml of oil. The observations were identical to Run 2A. Aqueous liquid was removed from the separatory funnels after flocculation and combined with samples from Run 2A. These samples, identified as TS-4B, were submitted to the laboratory for analysis.

A total of 490 ml of wet sludge was added to the centrifuge bottles. Again, a foam was noted at the surface of each container before centrifuging. The samples were dewatered in a centrifuge for 10 minutes at 1,500 rpm. The centrifuge dewatering results are summarized in Table 2.

Table 2. Centrifuge dewatering results of solids from Run 2.

Container	Wet Sludge Volume Before Centrifuging (ml)	Volume After Centrifuging Solids (ml)	Liquid (ml)
1	200	50	140
2	200	65	130
3	90	20	65

The solids were removed from the centrifuge bottles and submitted to the laboratory for analysis. These samples were identified as TS-5B.

Run 3

Run 3 consisted of 2 L of composite APL mixed with 120 ml of oil. The contents were added to two 2-liter separatory funnels, where the phases were allowed to separate for 30 minutes. Two liters of APL were removed from the funnels and placed into one 2-liter Erlenmeyer flask. The APL was a medium gray color.

Two grams of ferric chloride were added to the 2,000 ml of APL in the Erlenmeyer flask and swirled for 2 - 3 minutes. Ten milliliters of Betz polymer 1115L (1,000 ppm) were added to the flask, giving a final polymer concentration of 5 ppm. The solution was *mixed with a stirring rod* for several minutes. Equal amounts were poured into two 2-liter separatory funnels.

In contrast to the other two runs, a majority of the precipitate sank to the bottom of the two separatory funnels. Mixing the ferric chloride and the polymer with a stirring rod instead of swirling probably caused the floc to sink.

First, the sludge was removed through the bottom of the separatory funnels. Next, the aqueous liquid was removed from the separatory funnels and placed into laboratory sample bottles. These samples, identified as TS-4C, were then submitted to the laboratory for analysis.

A total of 540 ml of wet sludge was added to the centrifuge bottles. Foam was noted at the top of each centrifuge container. The samples were dewatered in a centrifuge for 10 minutes at 1,500 rpm. The centrifuge dewatering results are summarized in Table 3.

Table 3. Centrifuge dewatering results of solids from Run 3.

Container	Wet Sludge Volume Before Centrifuging (ml)	Volume After Centrifuging Solids (ml)	Liquid (ml)
1	200	55	140
2	200	50	135
3	140	25	115

The solids were removed from the centrifuge bottles and submitted to the laboratory for analysis. These samples were identified as TS-5C.

ANALYTICAL RESULTS AND CONCLUSIONS

Analytical results from the Phase III treatment process are presented in Tables 4 and 5. Based on the analytical data for organic compounds and heavy metals, the APL may be acceptable to Des Moines after the oil/water separation process. However, the oil and grease content of the APL after this stage was near the Metro limit of 100 parts per million (ppm). The amount of time the oil was in contact with the APL was only 24 hours. However, the ratio of oil to APL was considerably higher than was expected to occur in actual practice. This ratio of oil to APL also provided a more difficult test of the flocculation/sedimentation step. If these pretreatment levels are not acceptable to Des Moines, the City can present the data from the flocculation/sedimentation process.

Table 4. Analytical results of effluent from the Phase III oil/water separation and flocculation/sedimentation experiments.

Contaminant (Sample ID.)	APL (TS-1)	Oil (TS-2)	After Oil/Water Separation (TS-3)	After Oil/Water Sep. and Floc/Sedimentation Range (TS-4A,B,C)	Geo. Mean
VOCs (ppb):					
1,2-Dichloroethene	ND(20)	ND(1,900)	54	33-39	35.9
Ethylbenzene	ND(20)	31,000,000	340	230-250	239.9
Methylene Chloride	940	ND(9,400)	470 J	200-350	264.6
Toluene	ND(20)	ND(1,900)	ND(20)	11-14	12.4
Total Xylenes	ND(20)	65,000,000	680	440-580	506.8
PCBs (ppb)[a]:					
PCB 1242	15	430,000	240	2.4-7.1	3.7
PCB 1260	5.6	450,000	270	1.2-6.1	2.2
PAHs (ppb):					
Naphthalene	ND(50)	NA	330	24	NA
Acenaphthylene	ND(50)	NA	160	14-26	19.1
Acenaphthene	ND(50)	NA	65	ND(5)	NA
Fluorene	17	NA	320	9-14	11.8
Phenanthrene	37	NA	1,000	2.6-3.1	2.9
Anthracene	21	NA	220	3.6-5.8	4.6
Fluoranthene	83	NA	600	5.5-15	9.1
Pyrene	48	NA	380	3.5-9.7	5.9
Benzo(a)Anthracene	20	NA	170	1.9-3.7	2.7
Chrysene	17	NA	140	1.9-3.5	2.6
Benzo(b)Fluoranthene	ND(10)	NA	70	1.7	NA
Benzo(k)Fluoranthene	ND(10)	NA	ND(50)	1.1	NA
Benzo(a)Pyrene	ND(10)	NA	75	2.4	NA
Dibenzo(a,h)Anthracene	ND(50)	NA	250	ND(5)	NA
Indeno(1,2,3-cd)Pyrene	ND(10)	NA	ND(50)	1.1	NA
Metals (ppm):					
Cadmium	0.002	ND(2)	0.0018	0.0005-0.0011	0.0007
Chromium	0.08	50	0.20	0.05-0.11	0.07
Copper	0.05	15	0.07	0.14-0.15	0.14
Lead	0.17	ND(20)	0.11	0.005-0.012	0.007
Nickel	ND(0.03)	31	0.08	0.22-0.24	0.23
Zinc	0.68	13	0.44	0.14-0.20	0.16

Table 4. (continued) Analytical results of effluent from the Phase III oil/water separation and flocculation/sedimentation experiments.

Contaminant (Sample ID.)	APL (TS-1)	Oil (TS-2)	After Oil/Water Separation (TS-3)	After Oil/Water Sep. and Floc/Sedimentation Range (TS-4A,B,C)	Geo. Mean
Gen. Parameters:					
BOD (ppm)	93	NA	365	70-100	81.4
COD (ppm)	6,830	NA	1,500	1,090-1,200	1,128.9
Oil and Grease (ppm)	NA	NA	100	3.5-15	8.3
Suspended Solids (ppm)	350	NA	400	23	NA
Turbidity (NTU)	95	NA	55	5-6.9	5.7

[a] Aroclor 1242 and 1260 were the only PCBs detected in the APL.

ND(X) = Not detected at the specified detection limit (X).

J = Estimated concentration due to laboratory contamination.

NA = Not analyzed or not applicable.

Table 5. Analytical results of sludge from the Phase III oil/water separation and flocculation/sedimentation experiments.

Contaminant (Sample ID.)	Solids From Floc./Sed. After Centrifuging Range (TS-5A,B,C)	Geo Mean	Solids From Floc/Sed After Sand Filtration (TS-6)
TCLP Semi-Vols (ppb):			
1,4-Dichlorobenzene	10-15	11.8	NA
Naphthalene	36-46	41.4	NA
2-Methylnaphthalene	29-40	31.7	NA
Acenaphthylene	10-12	11	NA
Bis(2-Ethylhexyl)Phthalate	45	NA	NA
PCBs (ppb):			
PCB 1242	47-110	69	NA
PCB 1260	43-87	57.8	NA
TCLP Metals (ppm):			
Barium	0.59-0.87	0.72	NA
Chromium	0.03-0.04	0.03	NA
TPH (mg/kg)	4,900-14,000	9,320.3	NA
Weight (g)	67.83-94.22	79.9	2.83
Moisture (%)	95-97	96.2	74

NA = Not analyzed or not applicable.

The elevated concentration of PCBs and PAHs in the APL after oil/water separation is probably due to the presence of oil. These contaminants are transferring to the APL from the oil, but at levels below their solubility in water. We recommend the City present the data to Des Moines before and after flocculation. If Des Moines is unwilling to accept these levels of volatile compounds, we can aerate the treated APL or use processes that will promote the volatilization of the compounds of concern.

Analytical results from the second step in the Phase III treatment process, flocculation/sedimentation, indicated that all parameter levels had decreased. Comparison of the effluent concentrations of certain compounds of concern before flocculation ("After Oil/Water Separation" column) and after flocculation show average decreases of the following magnitudes: VOCs 27%, PCBs 99%, metals 33%, BOD 78%, COD 25%, and oil and grease 92%. Although the VOC levels exceeded the performance goals, they appear to be within Metro's pretreatment standards found in the Kent Highlands/Midway discharge permits and other discharge permits. All the other parameters met the performance goals.

The COD of the APL was not markedly reduced after the flocculation process. Iron, added to the system as ferric chloride, may increase the COD. Possibly, Des Moines would accept the treated APL with the reduced COD levels.

Data from the froth flotation experiment in Phase I indicated the level of volatile compounds in the APL is easily reduced through aeration. If considered necessary by Des Moines, this additional processing step will be conceptually designed and costed in the feasibility study. Official word from Des Moines will not be available until after the treatability study report is produced.

The oil/water separation and flocculation/sedimentation processes also will be conceptually designed and costed in the treatability study report. The report will also include the conceptual design and cost of a filter press system for dewatering the flocculation sludge. A design assumption will be made that the solids can be dried to have 90% of their moisture by weight removed. Samples of the sludge will not be sent to a vendor for evaluation until pilot-scale studies are performed.

Also, as verified by Analytical Technologies, Inc., the detection of methylene chloride in the APL was due to laboratory contamination. Methylene chloride has not been detected in any APL samples taken from the Midway Landfill.

Appendix E

Costs

ALTERNATIVE 1. OIL/WATER SEPARATION ONLY.

Assumptions regarding Conceptual Design

Item	Assumptions
Oil/Water Separator	2000 gallons total capacity 700 gallon oil capacity-separate tank or internal 700 gallon sludge tank in front Fiberglass or carbon steel Includes level controller Containment berm, 4000 gal; 10' x 22' x 2'H Concrete pad; 15' x 30' x 10"; including preparation 40 gpm
Off-gas Venting	Venting of off-gases; piped to existing flare PVC pipe; small blower, backflash prevention
Electrical	Hook-up of controls, minor wiring
Instrument; controls	Shut-off assembly, alarm if overfill or blockage occur
Misc. plumbing	PVC pipe; includes insulation
Installation	Includes site prep; placement/assembly of Oil/Water separator, wiring, testing
Wastewater Discharge	$15.00/800 cubic feet charge rate per Des Moines; 40 gpm continuous flow over 30 years
Analytical/sampling	Twice weekly because of low intensity treatment: PCBs; Benzene compounds (BETX); Chlorinated Hydrocarbons (Cl HCs); Biological Oxygen Demand (BOD); Total Suspended Solids (TSS) analyzed Includes sampling, bottles, shipping
Oil disposal	2200 gal during first year; 220 gal/yr for years 2-10 oil collected in 55-gallon drums transported to TSCA-approved incinerator

ALTERNATIVE 1. OIL/WATER SEPARATION ONLY

CAPITAL COSTS

Direct Costs

Item	Brief Description	Unit Cost	Number	Total
Oil/Water separator	2000 gal, sludge tank, 700 gal oil storage	$ 19,750	1.0	$ 19,750
	contain. berm, 4000 gal; 10' x 22' x 2'H	$ 1,400	1.0	$ 1,400
	concrete pad; 15' x 30' x 10"; includes site prep	$ 250	13.889	$ 3,472
Off-gas Venting	per PMX	$ 11,320	1.0	$ 11,320
Electrical		$ 2,000	1.0	$ 2,000
Instrument; controls		$ 3,000	1.0	$ 3,000
Misc. plumbing	lump sum; incl insulation	$ 5,000	1.0	$ 5,000
Installation	includes site prep	$ 20,000	1.0	$ 20,000
TOTAL, DIRECT COSTS	Oil/Water Separation			$ 65,942

Indirect Costs

Administration	5% of total direct cost (TDC)	$ 65,942	0.05	$ 3,297
Engineering	15% of TDC	$ 65,942	0.15	$ 9,891
Shipping	2% of TDC	$ 65,942	0.02	$ 1,319
Permits	4% of TDC	$ 65,942	0.04	$ 2,638
Sales Tax	8.1% of TDC	$ 65,942	0.081	$ 5,341
Contingency	20% of TDC	$ 65,942	0.2	$ 13,188
Startup/Shakedown	2% of TDC	$ 65,942	0.02	$ 1,319
TOTAL, INDIRECT COSTS		Oil/Water Separation Only		$ 36,993

OPERATION AND MAINTENANCE COSTS

Item	Description	Unit Rate	Number	Total
Wastewater Discharge	$15.00/800 cf; 40 gpm	$ 15.00	3513.14	$ 52,697
Analytical/sampling	2x Weekly: PCBs; BETX; Cl HCs BOD; TSS includes sampling, bottles, shipping	$ 800.00	104	$ 83,200
Electrical	estm 0.5 HP total power = 0.3 kW	$ 0.06	1095	$ 66
Oil disposal	2200 gal yr 1; 220 gal/yr for yr 2-10 per 55 gal	$ 825.00	76	$ 62,700
	oil transport, per trip	$ 200.00	22	$ 4,400
Maintenance	cleaning, misc	$ 8,000.00	1	$ 8,000
Maintenance: venting	8 hr/mo	$ 45.00	96	$ 4,320
TOTAL, ANNUAL OPERATION & MAINTENANCE COSTS (excluding oil disposal)				$ 148,283
Total, oil disposal cost				$ 67,100

COST SUMMARY OF ALTERNATIVE 1. OIL/WATER SEPARATION ONLY

			Factor	
TOTAL, CAPITAL COST	Oil/Water Separation Only			$ 102,935
PRESENT WORTH OF ANNUAL O&M COST (excl. oil disposal)		3% interest	19.6	$ 2,906,347
		5% interest	15.372	$ 2,279,406
		10% interest	9.427	$ 1,397,864
PRESENT WORTH, OIL DISPOSAL		3% interest		$ 60,788
		5% interest		$ 57,227
		10% interest		$ 50,097
PRESENT WORTH, TOTAL		3% interest		$ 3,070,070
		5% interest		$ 2,439,568
		10% interest		$ 1,550,896

ALTERNATIVE 3a. OIL/WATER SEPARATION WITH FLOCCULATION	8 hr/d operation

Assumptions Regarding Conceptual Design

Item	Assumptions
Oil/Water Separator	Same as in Alternative 1
APL holding tanks	22,000 gallon capacity; carbon steel; covered, vented Sized to hold approx 16 hr flow at 40 gallons per minute (gpm) Includes oil skimmers, level controllers centrifugal pumps: 160 gpm; indpt operation; Pumps covered by small pumphouse Concrete pad and site prep to place tank Containment berm holds 100% tank capacity Outdoor storage
Ferric Sulfate Makeup Tank	Ferric sulfate added as concentrated solution 2000 gal Polyethylene for chemical compatibility Located within building Mixer to keep chemicals suspended, dissolved
Polymer Tank	600 gallon steel tank with piping, controls Storage of hydrated polymer Metering pump feeds polymer; incl shut-of assembly Polymer added in-line Indoor storage Cationic, high charge density
Flocculent mixing tank	2500 gallon Polyethylene for chemical compatibility 15 minute hydraulic retention time Low agitation mixer to provide flocculent contact Tank stored inside Off-gases collected and incinerated No pH adjustment
Clarifier	Concrete clarifier, 6' high, 22' diam; 380 sf surface area Sized for 160 gpm Hydraulic loading: 540 gallon/day/square foot (gpd/sf) Solids loading: 5 lb/day/sf Complete with piping, site prep and excavation; equipment; concrete, steel, labor, electrical and installation Outdoor location Off-gases collected and incinerated Estimate 10% solids, 90% treated water
Solids holding tank	5000 gallon rectangular, carbon steel; cover Sized for 16 gpm; 5 hr holding Twin mixers to keep solids suspended Vented to existing flare Outdoor storage Mixers: 16" turbine; 2 HP Moyno pump connected near tank; pumphouse to protect pump

Filter Press	Based on 16 gpm; 1 ppm solids influent; 30 weight percent (w%) solids out 25 plates; 24" square plates; 100 psi 95% solids capture Manual operation Compressor to provide 100 psi air Air diaphragm pump Filtrate recycled to mixing tank
Venting System	Collection, blower system for oil/water separator, APL tanks, mixing tank, clarifier, solids holding tank PVC pipe, backflash preventors; incinerated with existing flare
Building	3000 square feet; industrial building Houses selected equipment, reagents, electrical controls Insulated; Heating, ventilation, air conditioning (HVAC) with additional fans; Lights, electrical; Large garage doors for equipment access Worker amenities incl showers, change room, lunchroom Equipped with health and safety gear Raised roof
Sludge Handling System	Sub-grade floor; covered holding bin Sludge drops into holding bin; Bins transported off-site Approx 3/4 cubic yard sludge per day
Electrical	Hook-up of pumps, motors, controls, control panel
Instrument; controls	Overfill monitors, level controls with feedback to well shut-off
Misc plumbing	PVC pipe, incl pipe insulation
Sludge Disposal	Disposal at Cedar Hills landfill; $6/ton transport 1500 pounds per day Tipping fee of $79/ton
Wastewater Discharge	$15.00/800 cubic feet (cf); 40 gpm
Analytical/sampling	Same analytes as in Alternative 1. One-half as many samples as option 1 because of more rigorous treatment
Operator	2 operators; $25/hr; 8 hr/d; 7 d/wk Trained technicians
Polymer	55-gal drums; 465 lb/drum 2.4 lb/day polmer based on dose of 5 ppm
Ferric Sulfate	453 lb/day = 0.23 ton/day Based on dose of 1 gram/liter
Electrical	10 hour per day at full power
General Maintenance	Filters, H&S equipment; motor service; clean
Oper/maint of venting	8 hr/mo; $45/hr
Oil disposal	Same as in Alternative 1
Maint of O/W separator	Periodic cleaning of internal corrugated plates

ALTERNATIVE 3a. OIL/WATER SEPARATION WITH FLOCCULATION	8 hr/d operation

CAPITAL COSTS

Direct Costs

Item	Brief Description	Unit Cost	Number	Total
Oil/Water separator	2,000 gal; 700 gal sludge, 700 gal oil storage	$ 19,750	1	$ 19,750
	contain. berm, 4,000 gal; 10' x 22' x 2' H	$ 1,400	1	$ 1,400
	concret pad, 15' x 30' x 10"; per CY, incl prep	$ 250	13.8889	$ 3,472
APL holding tanks	22,000 gal; carbon steel; covered, vented	$ 27,500	2	$ 55,000
	incl oil skimmers; level controllers	$ 1,500	2	$ 3,000
	pumps: 160 gpm; 1 HP; centrfgl; incl housing	$ 2,000	2	$ 4,000
	contain. berm: 44,000 gal; 35' x 35' x 7' H	$ 7,300	1	$ 7,300
	concrete pad, 35' x 35' x 1'; per CY incl prep	$ 250	45.3704	$ 11,343
Ferric Sulfate	450 lb/d; 25% soln; 15 day storage			
Makeup Tank	2k gal PE tank; hoppr; piping; pump; cntrol	$ 4,350	1	$ 4,350
	1 HP mixer	$ 2,000	1	$ 2,000
Polymer Tank	600 gal; steel; piping, controls	$ 1,800	1	$ 1,800
	1 HP mixer; 14" turbine	$ 1,775	1	$ 1,775
	metering pump	$ 2,000	1	$ 2,000
Flocculent mixing tank	2,500 gal; Polyethylene; piping, pump, controls	$ 4,800	1	$ 4,800
	0.75 HP mixer, 100 rpm, 31" impeller	$ 4,071	1	$ 4,071
Clarifier	concrete clarifier, 6' H, 22' diam; 380 sf compl: pipe; excav; site prep; eqmt; concr steel, labor, electr & install	$110,000	1	$110,000
Solids holding tank	5000 gal, rect, carbon steel; cover	$ 6,000	1	$ 6,000
	mixers: 16" turbine; 2 HP	$ 2,210	2	$ 4,420
	Moyno pump; 1 HP; incl housing	$ 2,500	1	$ 2,500
Filter Press	16 gpm; 1 ppm solids in; 30 weight % solids out; 25 plates; 24" square plates; 100 psi	$ 16,000	1	$ 16,000
	compressor, air diaphragm pump	$ 5,000	1	$ 5,000
Venting System	per Parametrix	$ 14,160	1	$ 14,160
Building	with pad; for controls, filter press, reagent tanks; reagent storage; 3,000 sf; unit cost per sf insulated, heat, lights, vent, shower, lunchrm	$ 100	3000	$300,000
Sludge Handling System	Sub-grade floor; covered holding bin	$ 15,000	1	$ 15,000
Electrical	per HP	$ 800	15	$ 12,000
Instrument controls		$ 15,000	1	$ 15,000
Misc plumbing	lump sum; includes insulation	$ 14,000	1	$ 14,000
Installation	excludes dissolved air flotation cell or clarifier	$ 25,000	1	$ 25,000
TOTAL DIRECT COST	Oil/Water Separation + Flocculation Option			$665,141

Indirect Costs

Item	Percent of Total Direct Cost (TDC)	TDC	Factor	Total
Administration	5% of TDC	$665,141	0.05	$ 33,257
Engineering	10% of TDC	$665,141	0.1	$ 66,514
Shipping	2% of TDC	$665,141	0.02	$ 13,303
Permits	2% of TDC	$665,141	0.02	$ 13,303
Sales Tax	8.1% of TDC	$665,131	0.081	$ 53,876
Contingency	20% of TDC	$665,141	0.2	$ 133,028
Startup/Shakedown	2% of TDC	$665,141	0.02	$ 13,303
TOTAL, INDIRECT COST	Oil/Water Separation + Flocculation Option			$ 326,584

OPERATION AND MAINTENANCE COSTS

Item	Description	Unit Rate	Number	Total
Sludge Disposal	Disposal at Cedar Hills; $6/ton transport	$ 84.00	273.75	$ 22,955
Wastewater Discharge	$15.00/800 cubic feet; 40 gpm	$ 15.00	3513.14	$ 52,697
Analytical/sampling	Weekly: PCBs; BETX; Cl HCs; BOD; TSS includes sampling, bottles, shipping	$ 800.00	52	$ 41,600
Operator	2 operators: $25/hr; 8 hr/d; 7 d/wk	$ 25.00	5,840	$ 146,000
Polymer	55-gal drums; 465 lb/drum 2.4 lb/day	$ 2.32	875.27	$ 2,031
Ferric Sulfate	453 lb/day = 0.23 ton/day	$ 350.00	83.95	$ 29,383
Electrical	estm 15 HP total power = 11 kW	$ 0.06	40150	$ 2,409
General Maintenance	filters; Health & Safety eqmt; motor service	$10,000.00	1	$ 10,000
Oper/maint of venting	8 hr/mo; $45/hr	$ 45.00	96	$ 4,320
Oil disposal	2200 gal in yr 1; 220 gal/yr in yrs 2-10; per 55 gal	$ 825.00	76	$ 62,700
	oil transport, per trip	$ 200.00	22	$ 4,400
Maintain Oil/Water separator	cleaning, misc	$ 2,000.00	1	$ 2,000
TOTAL, ANNUAL OPERATION & MAINTENANCE COSTS (excluding oil disposal)				$ 313,435
Total, oil disposal cost				$ 67,100

COST SUMMARY, ALTERNATIVE 3a. OIL/WATER SEPARATION PLUS FLOCCULATION

TOTAL CAPITAL COST	Oil/Water Separation + Flocculation 8hr/d operation			$ 991,725

			Factor	
PRESENT WORTH OF ANNUAL O&M COSTS (excl oil disposal)		3% interest	19.6	$ 6,143,326
		5% interest	15.372	$ 4,818,123
		10% interest	9.427	$ 2,954,752

PRESENT WORTH, OIL DISPOSAL	3% interest	$ 60,788
	5% interest	$ 57,227
	10% interest	$ 50,097

PRESENT WORTH, TOTAL	3% interest	$ 7,195,839
	5% interest	$ 5,867,075
	10% interest	$ 3,996,574

ALTERNATIVE 3b. OIL/WATER SEPARATION WITH FLOCCULATION	24 hr/d manned operation

Assumptions Regarding Conceptual Design

Item	Assumptions
Oil/Water Separator	Same as in Alternative 1
APL holding tanks	Not included - storage not needed
Fe Sulfate Makeup Tank	Same as for Alternative 3a
Polymer Tank	Same as for Alternative 3a
Flocculent mixing tank	650 gallon Polyethylene for chemical compatibility 40 gpm Same as Alternative 3a otherwise
Clarifier	Concrete clarifier, 6' high, 11' diam; 95 sf surface area Sized for 40 gpm Same as for Alternative 3a otherwise
Solids holding tank	Sized for 4 gpm continuous; 20 hour storage Same as for Alternative 3a otherwise
Filter Press	Same as for Alternative 3a; operates 8 hr/day
Venting System	Same as for Alternative 3a
Building	Same as for Alternative 3a
Sludge Handling System	Same as for Alternative 3a
Electrical	Hook-up of pumps, motors, controls, control panel
Instrument; controls	Added controls for continuous opeation
Misc plumbing	Same as for Alternative 3a
Sludge Disposal	Same as for Alternative 3a
Wastewater Discharge	Same as for Alternative 3a
Analytical/sampling	Same as for Alternative 3a
Operator	2 operators: $25/hr; 24 hr/d; 7 d/wk Trained technicians
Polymer	Same as for Alternative 3a
Ferric Sulfate	Same as for Alternative 3a
Electrical	Same as for Alternative 3a
General Maintenance	Same cost as for Alternative 3a; eqmt runs continuously
Oper/maint of venting	Same as for Alternative 3a
Oil disposal	Same as for Alternative 3a
Maint of Oil/W separator	Same as for Alternative 3a

ALTERNATIVE 3b.	OIL/WATER SEPARATION WITH FLOCCULATION 24 hr/d manned operation

CAPITAL COSTS

Direct Costs

Item	Brief Description	Unit Cost	Number	Total
Oil/Water separator	2,000 gal; 700 gal sludge, 700 gal oil storage	$ 19,750	1	$ 19,750
	contain. berm, 4,000 gal; 10' x 22' x 2' H	$ 1,400	1	$ 1,400
	concret pad, 15' x 30' x 10"; per CY, incl prep	$ 250	13.8889	$ 3,472
Ferric sulfate makeup tank	450 lb/d; 25% soln; 15 day storage; 2,000 gal Polyethyln (PE) tank; hoppr; pipe; pump; cntrl	$ 4,350	1	$ 4,350
	1 HP mixer	$ 2,000	1	$ 2,000
Polymer tank	600 gal; steel; piping, controls	$ 1,800	1	$ 1,800
	1 HP mixer; 14" turbine	$ 1,775	1	$ 1,775
	metering pump	$ 2,000	1	$ 2,000
Flocculent mixing tank	650 gal; PE, piping, pump, controls	$ 3,400	1	$ 3,400
	0.5 HP mixer, 100 rpm, 16" impeller	$ 1,800	1	$ 1,800
Clarifier	concrete clarifier, 6' H, 11' diam; 95 sf complete: pipe; excav; site prep; eqmt; concrete, steel, labor, electr & install	$ 78,000	1	$ 78,000
Solids holding tank	5,000 gal, rect, carbon steel; cover	$ 6,000	1	$ 6,000
	mixers: 16" turbine; 2 HP	$ 2,210	2	$ 4,420
	Moyno pump; 1 HP; incl housing	$ 2,500	1	$ 2,500
Filter Press	16 gpm; 1 ppm solids in; 30 weight % solids out; 25 plates; 24" square plates; 100 psi	$ 16,000	1	$ 16,000
	compressor, air diaphragm pump	$ 5,000	1	$ 5,000
Venting System	per Parametrix	$ 14,160	1	$ 14,160
Building	with pad; for controls, filter press, reagent tank; reagent storage; 3,000 square feet (sf); per sf insulated, heat, light, ventil, showr, lunchrm	$ 100	3000	$300,000
Sludge Handling System	Sub-grade floor; covered holding bin	$ 15,000	1	$ 15,000
Electrical	per HP	$ 800	12	$ 9,600
Instrument controls		$ 18,000	1	$ 18,000
Misc plumbing	lump sum; includes insulation	$ 12,000	1	$ 12,000
Installation	excludes dissolved air flotation or clarifier	$ 23,000	1	$ 23,000
TOTAL DIRECT COST	Oil/Water Separation + Flocculation Option			$545,427

Indirect Costs

Item	Percent of Total Direct Cost (TDC)	TDC	Factor	Total
Administration	6% of (TDC)	$ 545,427	0.06	$ 32,726
Engineering	12% of TDC	$ 545,427	0.12	$ 65,451
Shipping	2% of TDC	$ 545,427	0.02	$ 10,909
Permits	2% of TDC	$ 545,427	0.02	$ 10,909
Sales Tax	8.1% of TDC	$ 545,427	0.081	$ 44,180
Contingency	20% of TDC	$ 545,427	0.2	$109,085
Startup/Shakedown	2% of TDC	$ 545,427	0.02	$ 10,909
TOTAL, INDIRECT COST	Oil/Water Separation + Flocculation Option			$284,168

OPERATION AND MAINTENANCE COSTS

Item	Description	Unit Rate	Number	Total
Sludge Disposal	Disposal at Cedar Hills; $6/ton transport	$ 84.00	273.75	$ 22,995
Wastewater Discharge	$15.00/800 cubic feet; 40 gpm continuous	$ 15.00	3513.14	$ 52,697
Analytical/sampling	Weekly: PCBs; BETX; Cl HCs; BOD; TSS includes sampling, bottles, shipping	$ 800.00	52	$ 41,600
Operator	2 operators: $25/hr; 24 hr/d; 7 d/wk	$ 25.00	17520	$438,000
Polymer	55-gal drums; 465 lb/drum 2.4 lb/day	$ 2.32	875.27	$ 2,031
Ferric Sulfate	453 lb/day = 0.23 ton/day	$ 350.00	83.95	$ 29,383
Electrical	estm 12 HP total power - 9 kW	$ 0.06	78840	$ 4,730
General Maintenance	filters, Health & Safety eqmt; motor service	$10,000.00	1	$ 10,000
Oper/maint of venting	8 hr/mo; $45/hr	$ 45.00	96	$ 4,320
Oil disposal	2,200 gal in yr 1; 220 gal/yr in yrs 2-10; per 55 gal	$ 825.00	76	$ 62,700
	oil transport, per trip	$ 200.00	22	$ 4,400
Maintain Oil/W Seprt	cleaning, misc	$ 2,000.00	1	$ 2,000
TOTAL, ANNUAL OPERATION & MAINTENANCE COSTS (excluding oil disposal)				$607,755
Total, oil disposal cost				$ 67,100

COST SUMMARY, ALTERNATIVE 3b. OIL/WATER SEPARATION PLUS FLOCCULATION

TOTAL CAPITAL COST	Oil/Water Separation + Flocculation 24hr/d manned operation			$ 829,595

		Factor	
PRESENT WORTH OF ANNUAL O&M COSTS (excl oil disposal)	3% interest	19.6	$ 11,912,018
	5% interest	15.372	$ 9,342,425
	10% interest	9.427	$ 5,729,316

PRESENT WORTH, OIL DISPOSAL	3% interest	$ 60,788
	5% interest	$ 57,227
	10% interest	$ 50,097

PRESENT WORTH, TOTAL	3% interest	$ 12,802,301
	5% interest	$ 10,229,247
	10% interest	$ 6,609,008

ALTERNATIVE 3c.	OIL/WATER SEPARATION WITH FLOCCULATION 24 hr/d operation; 8 hr manned; 16 hr auto

Assumptions Regarding Conceptual Design

Item	Assumptions
Oil/Water Separator	Same as in Alternative 1
APL holding tanks	Not included-storage not needed
Ferric Sulfate Makeup Tank	Same as for Alternative 3a
Polymer Tank	Same as for Alternative 3a
Flocculent mixing tank	650 gallon Polyethylene for chemical compatibility 40 gpm Same as Alternative 3a otherwise
Clarifier	Concrete clarifier, 6' high, 11' diam; 95 sf surface area Sized for 40 gpm Same as for Alternative 3a otherwise
Solids holding tank	Sized for 4 gpm continuous; 20 hour storage Same as for Alternative 3a otherwise
Filter Press	Same as for Alternative 3a; operates 8 hr/day
Venting System	Same as for Alternative 3a
Building	Same as for Alternative 3a
Sludge Handling System	Same as for Alternative 3a
Electrical	Hook-up of pumps, motors, controls, control panel
Instrument; controls	Added controls for automation: autodialer, level controls
Misc plumbing	Same as for Alternative 3a
Sludge Disposal	Same as for Alternative 3a
Wastewater Discharge	Same as for Alternative 3a
Analytical/sampling	Same as for Alternative 3a
Operator	2 operators: $25/hr; 8 hr/d; 7 d/wk Trained technicians
Polymer	Same as for Alternative 3a
Ferric Sulfate	Same as for Alternative 3a
Electrical	Same as for Alternative 3a
General Maintenance	Same cost as for Alternative 3a; eqmt runs continuously
Oper/maint of venting	Same as for Alternative 3a
Oil Disposal	Same as for Alternative 11
Maint of Oil/W Separator	Same as for Alternative 3a

ALTERNATIVE 3c.	OIL/WATER SEPARATION WITH FLOCCULATION 8 hr/d manned operation; 16 hr auto

CAPITAL COSTS

Direct Costs

Item	Brief Description	Unit Cost	Number	Total
Oil/Water separator	2,000 gal; 700 gal sludge, 700 gal oil storage	$ 19,750	1	$ 19,750
	contain. berm, 4,000 gal; 10' x 22' x 2' H	$ 1,400	1	$ 1,400
	concrete pad, 15' x 30' x 10"; per CY, incl prep	$ 250	13.8889	$ 3,472
Ferric sulfate makeup tank	450 lb/d; 25% soln; 15 day storage;2,000 gal Polyethylene (PE) tank; hoppr; pipes; pump; cntrol	$ 4,350	1	$ 4,350
	1 HP mixer	$ 2,000	1	$ 2,000
Polymer Tank	600 gal; steel; piping, controls	$ 1,800	1	$ 1,800
	1 HP mixer; 14" turbine	$ 1,775	1	$ 1,775
	metering pump	$ 2,000	1	$ 2,000
Flocculent mixing tank	650 gal; Polyethylene; piping, pump, controls	$ 3,400	1	$ 3,400
	0.5 HP mixer, 100 rpm, 16" impeller	$ 1,800	1	$ 1,800
Clarifier	concrete clarifier, 6' H, 11' diam; 95 sf complete: pipe; excav; site prep; eqmt; concrete, steel, labor, electr & installation	$ 78,000	1	$ 78,000
Solids holding tank	5000 gal, rect, carbon steel; cover	$ 6,000	1	$ 6,000
	mixers: 16" turbine; 2 HP	$ 2,210	2	$ 4,420
	Moyno pump; 1 HP; incl housing	$ 2,500	1	$ 2,500
Filter Press	16 gpm; 1 ppm solids in; 30% solids out 25 plates; 24" square plates; 100 psi	$ 16,000	1	$ 16,000
	compressor, air diaphragm pump	$ 5,000	1	$ 5,000
Venting System	per Parametrix	$ 14,160	1	$ 14,160
Building	with pad; for controls, filter press, reagent tanks; reagent storage; 3,000 sq feet; unit cost per sf insulated, heat, light, vent, shower, lunchrm, etc.	$ 100	3000	$300,000
Sludge Handling System	Sub-grade floor; covered holding bin	$ 15,000	1	$ 15,000
Electrical	per HP	$ 800	13	$ 10,400
Instrument controls	auto shut-off; level controls from flash mixer, chem tanks, clar, solids tank; autodialer	$ 30,000	1	$ 30,000
Misc plumbing	lump sum; includes insulation	$ 12,000	1	$ 12,000
Installation	excludes dissolved air flotation cell or clarifier	$ 23,000	1	$ 23,000
TOTAL DIRECT COST	Oil/Water Separation + Flocculation Option			$558,227

Indirect Costs

Item	Percent of Total Direct Cost (TDC)	TDC	Factor	Total
Administration	6% of TDC	$ 558,227	0.06	$ 33,494
Engineering	12% of TDC	$ 558,227	0.12	$ 66,987
Shipping	2% of TDC	$ 558,227	0.02	$ 11,165
Permits	2% of TDC	$ 558,227	0.02	$ 11,165
Sales Tax	8.1% of TDC	$ 558,227	0.081	$ 45,216
Contingency	20% of TDC	$ 558,227	0.2	$111,645
Startup/Shakedown	2% of TDC	$ 558,227	0.02	$ 11,165
TOTAL, INDIRECT COST	Oil/Water Separation + Flocculation Option			$290,836

OPERATION AND MAINTENANCE COSTS

Item	Description	Unit Rate	Number	Total
Sludge Disposal	Disposal at Cedar Hills; $6/ton transport	$ 84.00	273.75	$ 22,995
Wastewater Discharge	$15.00/800 cubic feet; 40 gpm continuous	$ 15.00	3513.14	$ 52,697
Analytical/sampling	Weekly: PCBs; BETX; Cl HCs; BOD; TSS includes sampling, bottles, shipping	$ 800.00	52	$ 41,600
Operator	2 operators: $25/hr; 8 hr/d; 7 d/wk	$ 25.00	5840	$146,000
Polymer	55-gal drums; 465 lb/drum 2.4 lb day	$ 2.32	875.27	$ 2,031
Ferric Sulfate	453 lb/day = 0.23 ton/day	$ 350.00	83.95	$ 29,383
Electrical	estm 13 HP total power = 10 kW	$ 0.06	87600	$ 5,256
General Maintenance	filters, Health & Safety eqmt; motor service	$10,000.00	1	$ 10,000
Oper/maint of venting	8 hr/mo; $45/hr	$ 45.00	96	$ 4,320
Oil disposal	2200 gal in yr 1; 220 gal/yr in yrs 2-10; unit cost per 55 gal	$ 825.00	76	$ 62,700
	oil transport, per trip	$ 200.00	22	$ 4,400
Maintain Oil w/seprt	cleaning, misc	$ 2,000.00	1	$ 2,000
TOTAL, ANNUAL OPERATION & MAINTENANCE COSTS (excluding oil disposal)				$316,282
Total, oil disposal cost				$ 67,100

COST SUMMARY, ALTERNATIVE 3c. OIL/WATER SEPARATION PLUS FLOCCULATION

TOTAL CAPITAL COST	Oil/Water Separation + Flocculation 8-hr manned; 16 hr auto			$ 849,064

		Factor	
PRESENT WORTH OF ANNUAL O&M COSTS (excl oil disposal)	3% interest	19.6	$ 6,199,127
	5% interest	15.372	$ 4,861,887
	10% interest	9.427	$ 2,981,590

PRESENT WORTH, OIL DISPOSAL	3% interest	$ 60,788
	5% interest	$ 57,227
	10% interest	$ 50,097

PRESENT WORTH, TOTAL	3% interest	$ 7,108,979
	5% interest	$ 5,768,178
	10% interest	$ 3,880,751